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CONTENTS

The Interpretation of the Triangular Basal Shadows in Roentgenograms of the Chest . . . . . G. E. RICHARDS, M.D. 289

Roentgenological Manifestations of Allergic Processes in Pulmonary Tuberculosis . . . . . MAX PINNER, M.D. 296

Public Health and Tuberculosis . . . . HENRY F. VAUGHAN, DR.P.H. 300

The Value of the Roentgen Ray in Apparently Healthy Children of School Age . . . . . D. S. BRACHMAN, M.D. 303

The Importance of the Roentgen Examination in the Modern Treatment of Pulmonary Tuberculosis . . . . . B. H. DOUGLAS, M.D. 305

Artificial Pneumothorax in a Group of Cases of Pulmonary Tuberculosis Formerly Looked upon as Hopeless . . . RICHARD MORGAN, M.D. 309

Collapse Therapy in Early Minimal Lesions of Pulmonary Tuberculosis E. J. O'BRIEN, M.D. 315

The Tuberculosis Problem in Detroit . . HENRY D. CHADWICK, M.D. 321

Calcification in Aortic and Mitral Valves: With a Report of Twenty-three Cases . . MERRILL C. SOSMAN, M.D., AND PAUL H. WOSIKA, M.D. 328

The Genealogy of the Roentgen Rays. (Continued from the August Issue) . . OTTO GLASSER, PH.D. 349

A Basis for the Comparison of Roentgen Rays Generated by Voltages of Different Wave Form . L. S. TAYLOR, G. SINGER, AND C. F. STONEBURNER 368

Energy Considerations in High Voltage Therapy . CHARLES C. LAURITSEN 380

The Physical Foundations of Chest Roentgenography. Part II. The Dependence of Sharpness upon Movement of Lung Tissues and Size of Focal Spot R. B. WILSEY 388

Editorials

Intravenous Urography in Children 402

Frederick H. Baetjer, 1874-1933 405

Society Proceedings, Correspondence and News Items 407

Book Reviews 413

Department of Technique

A Simple Technique for Roentgen Examination of the Petrous Pyramid MARCY L. SUSSMAN, M.D. 415

Index to Abstracts 419

Abstracts of Roentgen and Radium Literature 420

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THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

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THE INTERPRETATION OF THE TRIANGULAR BASAL SHADOWS IN ROENTGENOGRAMS OF THE CHEST*

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TO SAY that the use of lipiodol as an aid in the study of pulmonary disease has been a tremendous boon to both roentgenologist and internist and has greatly increased the accuracy of roentgen interpretation is an obvious platitude—but an excusable one. Especially has the use of this opaque oil been of service in connection with the study of bronchiectasis which is now revealed in a variety of forms previously unsuspected.

One of the problems upon which light has been thrown by this method of investigation has to do with the interpretation of the so-called triangular basal shadows occasionally seen in roentgen studies of the chest, a subject which upon first contact seems one of minor importance but which has been the means of bringing to our attention several facts of extreme interest not hitherto given much prominence in the study of chest pathology.

Most roentgenologists have been perplexed at one time or another by the presence of these shadows and, judging by the lack of satisfactory explanation in the literature, have failed to arrive at any entirely conclusive answer.

Singer and Graham,[12] in 1926, called attention to the condition and identified it as an atelectatic lower lobe, a phase of bronchiectasis. Their observations were verified during the surgical treatment of their cases but were not studied by means of opaque substances prior to operation to any extent.

Nitsch, in an interesting paper in 1901, makes reference to paravertebral triangular densities which were almost certainly these same triangular areas, though this work was not based upon roentgen investigations during life.

Sante[9] refers to the presence of bronchiectatic areas in the lower lobe hidden by the heart shadow and gives an illustration which is a typical example of the lesion to which the present paper refers.

But with these exceptions, English literature has been peculiarly silent regarding the condition until very recently, and it is probable that the finding was usually missed or at least misinterpreted by most observers.

Since our attention was first drawn to the finding it has been encountered 10 times in 2,000 consecutive routine chest examinations and would thus seem to be of sufficient importance to the clinical roent-

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27–30, 1932.

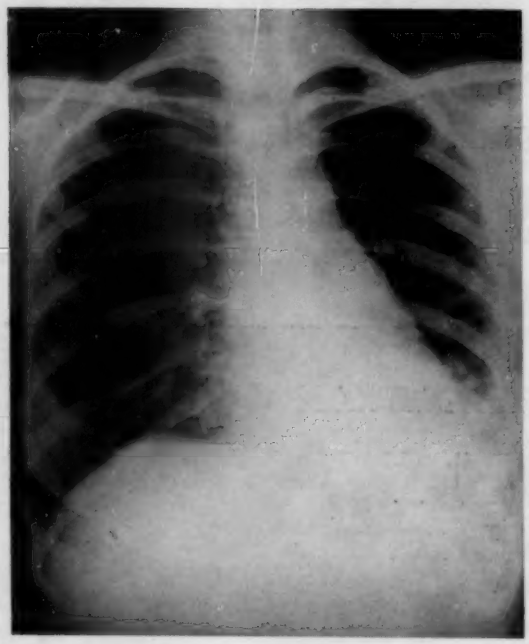

FIG. 1. Case 229,730. Typical unilateral lesion left side; triangular shadow hidden behind the heart.

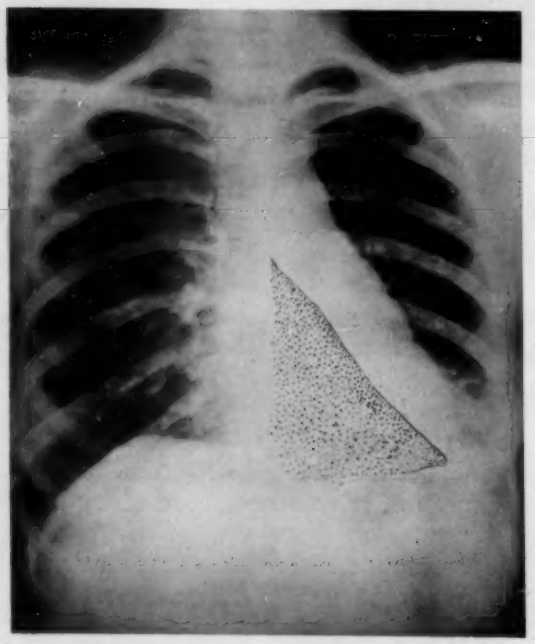

FIG. 2. Case 229,730. Same case retouched to indicate more clearly the outline of the shadow described.

genologist to justify again directing attention to it in view of our present methods of investigation.

The term "triangular basal shadow" is a fairly accurate descriptive term as the areas of increased density are usually more or less triangular in outline occupying the angle formed by the heart and diaphragm on either side of the vertebral shadow. The outer border of the areas is a straight or slightly curved line extending from above

FIG. 3. Case 229,730. Following introduction of lipiodol, showing extensive cylindrical bronchiectasis.

downward and outward to the diaphragm, thus completing the triangle. Many slight modifications of this general form are obviously quite possible and several are presented herewith.

1. *Typical Unilateral Shadow* (Figs. 1, 2, 3 and 4). This case shows a very characteristic shadow though somewhat difficult of demonstration because it is situated behind the heart shadow. In the original films there is to be seen a very definite area of increased density behind the heart, the outer border of which forms a sharp, well-de-

fined line of demarcation enclosing the whole cardiophrenic angle.

Following the injection of lipiodol it is at once seen that this entire area is composed of atelectatic lung containing numerous bronchiectatic cavities. Further, it is apparent that the area of lung involved represents the whole of the lower lobe of the involved side as may be seen by careful study of the distribution of the bronchial trunks.

FIG. 4. Case 229,730. Same film retouched to bring out: distribution of entire left lower bronchus to involved area; rotation of bronchus downward, and expansion of remaining lobe.

2. *Typical Bilateral Shadow* (Figs. 5, 6, 7 and 8). In this case the shadow on the right side is sufficiently typical to be described as triangular, while on the left it is more irregular in outline, yet conforming on the whole to such a description.

Following the injection of lipiodol it is again evident that the entire distribution of the right lower main bronchial trunk is within the involved area on the right side and the left lower main bronchus within a similar area on the left.

The conclusion reached by Singer and Graham, therefore, is confirmed that these are areas of atelectatic lung in which bronchiectasis is present. Two features of unusual interest are to be seen in these cases. The first is the small space which may

FIG. 5. Case 253,968. Typical bilateral shadows.

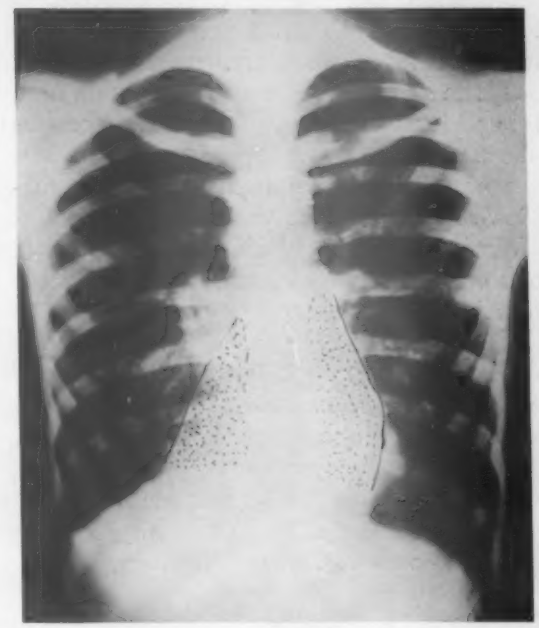

FIG. 6. Case 253,968. Areas retouched.

FIG. 7. Case 253,968. Following introduction of lipiodol.

be occupied by an entire lobe of lung when collapsed in this manner; the second the degree of rotation which the bronchi undergo.

In each case which has been observed on the left side the entire area of pathological density has been covered by the heart shadow. In one of these (Figs. 9 and 10), the shadow is a very small ovoid area lying along the side of the spine and is almost a perfect roentgen picture of tuberculous abscess complicating Potts's disease of the thoracic vertebrae. The diagnosis is immediately clarified by the use of lipiodol but would scarcely be possible by any other means.

On the right side the small space into which the lung may collapse is less striking but even here the entire lower lobe may be contained within the cardiohepatic angle.

Kerley[4] in a very interesting paper states that these areas are all collapsed accessory lobes, the lesion being originally a congenital anomaly.

"Schaffner found a well-developed fourth lobe in the right lung in fifteen per cent of normal individuals, and a third lobe in the left lung in a slightly smaller percentage. In no less than forty per cent of normal people evidence of accessory lobes can be found in a furrow running across the lower part of the lower lobes. These figures have since been verified by Müller and Gräberger .... Without any shadow of doubt, we are in a stage of human evolution when we are discarding a fourth lobe in the right lung and a third lobe in the left lung. The remnants of these lobes are a potent factor in the development of bronchiectasis."

Kerley's conclusion is that this lesion is always associated with such an accessory lobe. Whether this conclusion ultimately proves to be correct there seems no doubt that such lobes are much more common than has hitherto been known.

Rigler and Ericksen[7] in a paper now in process of publication has reviewed the literature and kindly allowed me to quote from their manuscript.

"Gråberger has recently called attention to the roentgenological manifestations of the basal median lobe of the lung, an accessory lobe occurring on either side, but it was first described by Rektorzik in 1861. It is therefore sometimes called the inferior accessory lobe of

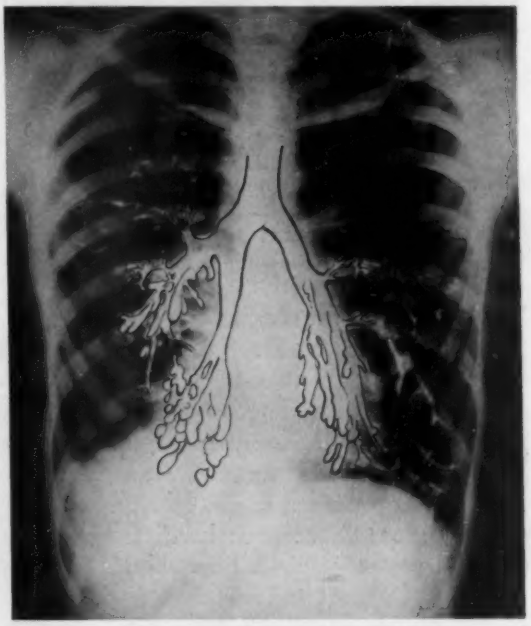

FIG. 8. Case 253,968. Tracing from Figure 7 to illustrate distribution of bronchus rotation, etc.

Rektorzik. It is well known to comparative anatomists that, almost without exception, a basal lung division, often called the cardiac or retrocardiac lobe, occurs on the right side in quadrupeds. The human inferior accessory lobe appears to develop from this heart lobe of animals and is supplied by the heart bronchus. When present on the left side it is supplied by the medial branch of the second anterior bronchus.

"Schaffner, in 1898, examined 210 human lungs post-mortem, and found this lobe to be present, partially or entirely formed, on either the right or left sides, in 45.7 per cent of the lungs.

"The incidence in the 210 lungs was as follows:

Completely formed, right side,	15 times
Completely formed, left side,	13 times
Completely formed, bilateral,	3 times
Partially formed, right side,	31 times
Partially formed, left side,	37 times
Partially formed, bilateral,	15 times."

Rotation. The second point of special interest in these cases is a natural result of the first, viz., the amount of downward rotation which the bronchi must undergo to permit the collapse of one lobe into so small a space and the corresponding expansion which must take place in the remaining lung in order to permit it to occupy the remaining thoracic space.

Fig. 9. Case 259,304. Small ovoid shadows lying close to spine simulating in original films tuberculous abscess or aneurysm. This is an example of accessory lobe.

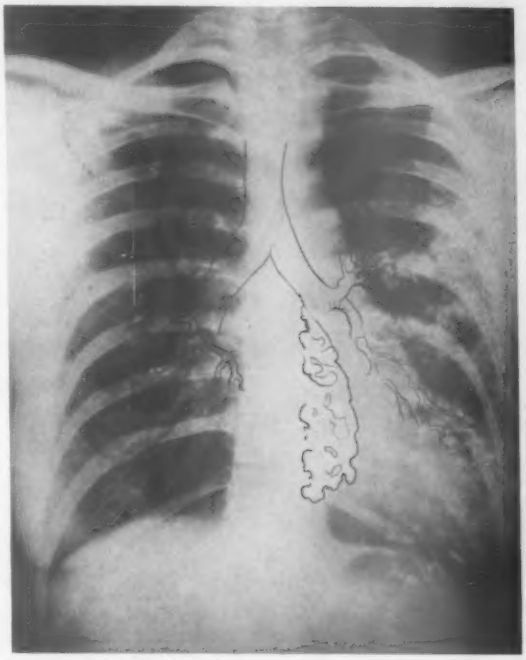

Fig. 10. Case 259,304. Tracing of Figure 9. Bronchus comes off low down posteriorly, probably accessory lobe. Unverified.

The degree of rotation which takes place is very clearly seen by comparing Figure 11, which is a normal right bronchial tree, with Figure 8, one of the cases presented. In this particular instance the bronchi have rotated downward through 27° and 18° respectively. This is no doubt an extreme example and would seem to be almost the limit of possible rotation, but in all of the cases studied this feature has been quite striking.

Equally interesting is the expansion of the remaining lung which in each case is seen to expand sufficiently to fill the entire remaining thoracic space.

Differential Diagnosis. When one comes to carefully analyze the cases in which the diagnosis has been established, it would seem that a correct diagnosis, even from

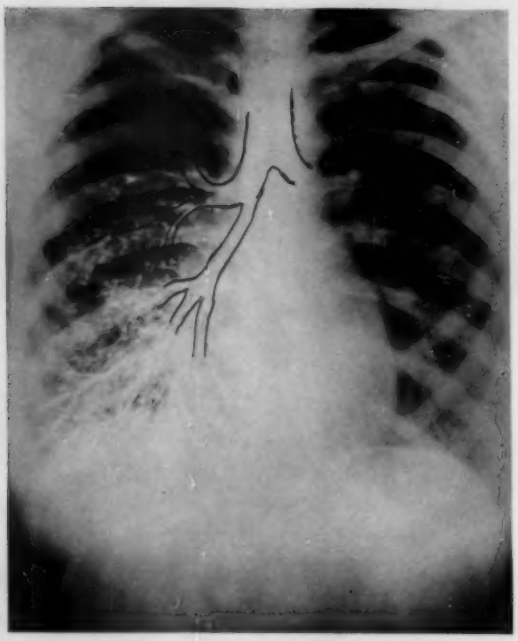

FIG. 11. Case 241,922. Tracing from normal bronchial tree for comparison with Figure 8 to illustrate downward rotation which bronchi undergo.

plain films without the opaque oil, should not present great difficulties, although it is obvious that lipiodol places within our hands the means of final demonstration.

Undoubtedly, the most common error in the past has been to consider these areas as due to pleural thickening and as they are observed rather infrequently this is perhaps a natural error. As soon, however, as a group of films showing the shadow are studied together this would be immediately apparent as an error and in the future will seldom be made. Equally apparent is the fact that the shadow is not adequately explained as an empyema or an area of pneumonic consolidation, though Rigler quotes a case of pneumonia occurring in one of the accessory lobes in this region. In one of our cases here presented (Fig. 9 prior to lipiodol), there might be justification for a diagnosis of either Pott's disease with abscess formation or aneurysm of the descending aorta, and in the absence of lipiodol it would be difficult, if not impossible, to reach a conclusive decision.

Kerley describes a case of tuberculosis occurring in a right lower accessory lobe, and several cases of primary carcinoma in such lobes have also been described. Thus the differential diagnosis renders the use of some opaque medium almost essential.

Finally, it will be noted that this form of atelectasis does not at all resemble in its roentgen appearances the massive atelectasis with which we are more familiar. At least in the cases we have had the opportunity to study there has been no elevation of the diaphragm, no shifting of the mediastinum and the shadow has always been comparatively small and confined to the paravertebral angle. In this group Figure 9 is considered to be an accessory lobe (though this is unverified) while in the others the main lower bronchus may be traced in its entirety into the involved lobe and we have felt convinced that an entire lobe, not merely an accessory or partial or accessory lobe, was involved in the collapse. This has been verified in those cases thus far operated upon.

The pathological physiology underlying the condition has been studied by Prof. Duncan Graham and Dr. W. P. Warner and reported by them in a separate communication. They have succeeded in producing the condition experimentally by obstructing the main bronchus, such obstruction, as might have been expected, being immediately followed by the development of a typical bronchiectasis.

The conclusion which one feels justified in reaching is that the finding of such shadows in roentgenograms of the chest is pathognomic of atelectasis with bronchiectasis. Our present opinion is that this may occur in accessory lobes as reported by Gråberger, Kerley, and others, but that it also commonly involves entire lobes of the lung and that roentgenologists should devote much more care to studies of the bases of the lung than they have done in the past. Careful reading of the articles by Kerley and Rigler and Ericksen is recommended to those interested in the subject.

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ROENTGENOLOGICAL MANIFESTATIONS OF ALLERGIC PROCESSES IN PULMONARY TUBERCULOSIS*

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THE subject of this presentation was chosen on account of the common experience that of all the various phases of pulmonary tuberculosis, the acute manifestations are most frequently misinterpreted. These acute phases are precisely the ones which, for therapeutic reasons, should be diagnosed without delay. But subjective symptoms, physical and roentgenological findings are frequently so uncharacteristic that the differential diagnosis is quite difficult. Another reason for the frequent misinterpretation of these acute phases is the customary representation of pulmonary tuberculosis as a strictly chronic disease. The exquisite chronicity of the disease as a whole is so impressive that intervening acute phases are readily overlooked or interpreted as intercurrent non-tuberculous diseases. Only since serial roentgenological studies at brief intervals have been made, during the last ten or fifteen years, has it become known how eminently important a rôle is played by acute phases.

Experimental work furnished a proper basis for the understanding of acute phenomena. The unmodified primary infection in an animal causes a characteristic slow development of specific lesions with a much delayed appearance of few clinical symptoms. When, however, the course of reinfections is studied, there appear strikingly acute phenomena, both in regard to anatomical changes and to constitutional symptoms. Allergy, the modified reactivity of the body caused by a previous infection, alters profoundly the development of infection.

Allergic reactions are well known in their morphological detail, in their causative mechanism, in their dependence on dosage and virulence of first and second infections, on the time interval between these two events and on the locus of reinfection. In experimental work where these details can be strictly controlled, it is more or less predictable whether a given reinfection will terminate in a prognostically more or less favorable development than an identical infection in a normal, non-infected animal. Such knowledge has caused an association between allergy and immunity which is undoubtedly much closer in the interpreting mind than in reality.

But without entering further into this much discussed theoretical phase, it must be apparent at once that all the factors that decide the outcome of an allergic phase (dosage, virulence, time interval, location) are totally uncontrollable and unanalyzable in clinical work. Therefore, no parallelism can be apparent between the allergic state of a patient and his immunity or resistance. Empirical observation confirms this theoretical conclusion: neither tuberculin tests (i.e. an intentional test for the allergic state), nor spontaneous allergic reactions permit of any judgment of the patient's immunological condition, or, in other words, of the prognosis.

The morphological characters of allergic reactions, pathological, roentgenological, and—to a limited extent—clinical, are fairly well established. Pathologically, they are represented in the lung as quickly developing, more or less circumscribed exudative foci which are in all essential respects not much different from banal bronchopneumonias. It is not pertinent here to discuss the differentiating details; the main fact of practical importance is their exudative character. The potentialities of their further development are: complete absorption,

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27–30, 1932.

caseation and excavation, and more or less complete fibrosis at any stage of the development. Their appearance, their absorption and their excavation proceeds at times with great speed, a general characteristic of allergic reactions.

Roentgenologically, allergic reactions produce focal areas of slight or medium density, usually fairly homogeneous in structure and with blurred, unsharp outlines which gradually fade out toward the normal parenchyma. Since such lesions may occur under a great variety of circumstances their more detailed characteristics cannot be given here with more precision.

The clinical manifestations, polymorphous to an extreme, will better be mentioned with the later more special discussion.

Such allergic phenomena appear with fair regularity at certain definite stages of the disease: (1) at the clinical onset; (2) as exacerbations of old foci; (3) at the initiation of new foci by bronchogenic spread, and (4) as terminal lower lobe pneumonias, so frequently diagnosed wrongly as nonspecific pneumonias.

(1) *Clinical Inception.** The most characteristic type of onset is the appearance of a single area of infiltration, usually more or less rounded, 2 to 5 cm. in diameter. Its localization is most frequent in the peripheral parts of the upper lobe, at the height of the second to third ribs; it is but rarely seen in the apex proper. It is, however, not rare to find it in the mid-lung field, particularly in the apex of the lower lobe. This latter localization is often misinterpreted as "hilar region," especially when no stereoscopic films are taken. The localization in the true hilar region is extremely rare. Basal foci occur and constitute particularly difficult differential diagnostic problems. The lesion here described is the *Frühinfiltrat* of the German literature; but its synonym "infraclavicular infiltration" should, as an obvious misnomer, disappear from medical usage. Roentgenologically, the etiological diagnosis is almost impossible. Any banal bronchopneumonia may have the identical appearance. Slight density and localization in the upper lobes speak somewhat in favor of tuberculosis.

In some cases the roentgenologically demonstrable onset is preceded by a long history of symptoms suggestive of tuberculosis, fatigue, loss of weight and muscular tone, and slight elevations of temperature. It is still a matter for speculation whether such preceding symptoms are caused by an undetectable tuberculous focus, or by a non-tuberculous disorder which prepared the soil for tuberculosis. In some other cases, subjective symptoms are almost or totally absent. The majority of patients, however, exhibit a symptomatology which is characteristic enough, although totally different from what is still taught to be the characteristic syndrome of incipient tuberculosis. The onset is sudden, though frequently not acute in the sense of severe; it is marked by the symptoms of a "heavy cold" or a slight "flu" without particular emphasis on respiratory symptoms. There is a moderate elevation of temperature of a few days' duration, although slight subfebrile temperatures may continue for a long time. The general well-being is not much disturbed, but the return to a completely normal level is unduly delayed. Altogether the patient with a small initial tuberculous bronchopneumonia feels and looks less ill than the patient with a comparable non-tuberculous bronchopneumonia. This discrepancy between marked roentgenological findings and the paucity of clinical signs and symptoms is probably the most important differential diagnostic point. Similarly, the blood picture is less disturbed in tuberculosis, the total white count hovers usually near or slightly above the upper limits of normal, there is no or slight neutrophilia, no or slight shift to the left, and toxic changes in the leucocytes are almost always absent. The local physical signs do not contribute to the differential diagnosis, although complete absence

* When this paper was presented it was illustrated by lantern slides of chest roentgenograms of representative cases. For purposes of publication it seemed advisable to omit individual case reports and to emphasize more the general features.

is more frequent in tuberculosis. The later developments are not under discussion here; they may produce roentgenological pictures that are practically diagnostic (cavitation, fibrosis); but it should be kept in mind that rather rapid clearing is no argument against the diagnosis of tuberculosis. In the very earliest phases, sputum and bacilli may be absent, but they may appear during the period of absorption.

Another, but much less frequent, type of onset is characterized by the sudden appearance of a massive, at times lobar, infiltration. These cases are at the onset almost invariably diagnosed as lobar pneumonia roentgenologically; and, indeed, there is nothing to differentiate the two diseases by the roentgen ray. But these patients exhibit still more strikingly the discrepancy between anatomical involvement and symptomatology. This usually permits of making the diagnosis before tubercle bacilli are found in the sputum, ordinarily an early occurrence. It will be good to remember that labial herpes is excessively rare in uncomplicated tuberculosis.

A third type of onset, frequently puzzling to the roentgenologist, shows many widely scattered, fluffy, roundish shadows. They are usually ill defined, of slight density and homogeneous. Often, the distribution is fairly symmetrical and more dense in the upper portions. The size of the individual shadows may be fairly uniform or may vary greatly. When all shadows are fairly large, say 1 to 3 cm. in diameter, the picture is quite similar to the one produced by multiple tumor metastases, especially from a hypernephroma. When all the shadows are small, the picture may simulate pneumoconiosis. The clinical features of such cases —most likely due to hematogenous seeding —need a good deal more study. However, these patients, too, show at times an appalling paucity of symptoms compared with their extensive involvement. Not infrequently, such patients make a rather unexpected recovery, associated roentgenologically by apparently complete clearing, by fibrosis or by calcification. Unless excavation develops, the sputum is always scanty and tubercle bacilli are rare. (A special study of this type of non-miliary hematogenous pulmonary tuberculosis will be presented in the near future.)

The three roentgenological manifestations mentioned: isolated infiltrations, massive, sometimes lobar infiltrations and multiple, probably hematogenous infiltrations, account probably for the vast majority of all cases of pulmonary tuberculosis in the adult as far as the clinically and roentgenologically initial lesion is concerned.

(2) *Exacerbations of Old Foci.* Old, more or less healed tuberculous foci, make the roentgenological manifestations of more or less extensive areas of fibrosis or calcification. There is, however, little doubt that anatomical scars of tuberculous foci may escape roentgenological detection, either by virtue of their location (mediastinal or diaphragmatic shadow) or by virtue of their size. The radiopacity of fibrotic scars may be compensated by circumfocal emphysema. Exacerbations of old foci manifest themselves roentgenologically as fluffy, ill-defined shadows surrounding old foci: circumfocal infiltrations. They develop within the course of a few days, usually accompanied by symptoms and signs similar to the ones seen at the clinical onset of the disease. These infiltrations may promptly absorb. In other cases they are the inception of a period of active and progressive disease; and then the infiltrations undergo the same progressive changes as do initial foci.

From a standpoint of prevention and prognosis it would be important to know what type of old foci are more or less likely to undergo exacerbations. Nothing very definite is known about this question, but a few empirical impressions may be mentioned. Exacerbations seem to be quite rare around isolated, calcified primary foci (Ghon tubercles), especially in adults. They are relatively frequent around multiple calcified foci, the residues of non-miliary hematogenous pulmonary tuberculosis men-

tioned above. The characteristic process is the appearance of thin perifocal shadows simultaneously around a number or all calcified foci present. This is apt to initiate rapid progressive destruction with the formation of large cavities. Strictly apical foci, fibrotic or calcified, seem to exacerbate much less frequently than subapical foci. In general, the impression is gained that the likelihood of exacerbations decreases with increasing age of the patient. These are a few principles based on roentgenological evidence. Needless to say that the likelihood of exacerbations depends largely on the clinical status of the patient.

(3) *Bronchogenic Metastases.* In the course of an active pulmonary tuberculosis new territory is frequently invaded by bronchogenic spread. Invasion of previously normal parenchyma is, as a rule, manifested by an acute infiltrative lesion of the same type and of the same potentialities as initial infiltrative lesions. Since they are added to the background of an already existing disease they are not infrequently overlooked. Their roentgenological characteristics are essentially similar to initial foci; often they are fairly large and may consist of coalescing clusters of shadows. In rare instances they occur without any associated symptoms; frequently the symptoms, when not checked up by roentgen studies, are interpreted as a "cold."

(4) *Terminal Bronchopneumonias.* Probably the most frequent single direct cause of death in pulmonary tuberculosis is massive bronchogenic spread in the lower parts of the lung. This process is frequently diagnosed as non-tuberculous pneumonia. The roentgenological manifestation of this process is a massive infiltrative lesion, usually unilateral, at times bilateral. The internal structure of the shadow shows often a cloud-like unevenness, suggesting multiple centers of dense (probably caseous) infiltration surrounded by less opaque exudation. The significance of such a lesion lies in its finality and not in any therapeutic consideration.

SUMMARY AND CONCLUSIONS

The important landmarks in the progression of pulmonary tuberculosis are signalized by acute exudative lesions whose pathological bases are tuberculous bronchopneumonias. Roentgenologically they are manifested by the characteristic shadows produced by exudative lesions. Their appearance should more often than is the case today suggest the diagnosis of tuberculosis, although these shadows *per se* are not pathognomonic of tuberculosis. In conjunction with the clinical and laboratory findings the diagnosis is usually made without much difficulty. But it should be emphasized that without roentgenological studies a vast number of such lesions will remain undiagnosed and even unsuspected.

Whenever uninvolved pulmonary tissue is invaded by tubercle bacilli the tissue responds by acute infiltrative reactions; hence their appearance at the clinical onset of the disease (in previously infected individuals), at new focalizations and at exacerbations. These allergic reactions contain all the potentialities of complete resorption, progressive destruction and healing by fibrosis or (in some cases) by calcification. The prognosis at the onset of each such reaction must be guarded, but the possibility of definitely benign developments should not be underrated. Even if the final course is progression, the immediate development is often regressive. This explains the apparent paradox that the exquisitely chronic course of tuberculosis is composed of a series of acute phases. Most of the acute phases are followed by periods of retrogression and partial repair; and these intervening periods lend to the disease its chronic nature.

PUBLIC HEALTH AND TUBERCULOSIS*

By HENRY F. VAUGHAN, DR.P.H.
Commissioner of Health
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YOU have, as roentgen-ray experts, been looking at the tuberculosis problem from a rather short distance. We wish to take you away from that near aspect temporarily and have you look at it from the broader community viewpoint.

Your President, Dr. Evans, has indicated that the roentgen ray is one of the most important implements for finding the early case of tuberculosis. What is true of tuberculosis is equally true of another disease which now ranks among the leading and most important causes of death, cancer. Although the tuberculosis death rate has declined during the last two or three decades in a very startling fashion, this disease is still one of our most important single causes of death. Cancer is rapidly nearing the top of the list. There are no two diseases in which health departments are now more interested and in which the roentgenologist plays such an important part. At this time with critical financial conditions confronting all health departments, not to mention the physician in private practice, there is greater need than ever before for cooperation and integration of all existing health machinery in each community. By health machinery we mean the public which is really the beneficiary of any action, the medical profession, dental profession, and the public health agencies, whether of an official or non-official character.

We have had some experience in Detroit with such a cooperative plan during the past several years. We visualized a situation wherein there are some 1,500 practitioners of medicine and one health department, and it occurred to us that the 1,500 physicians could do far more to preserve the public health than could a single health department. If we could bring together the facilities of these two organizations we could expect great results.

There is nothing more irritating to the average physician than a free clinic operated by a health department. So we started out, in cooperation with the Wayne County Medical Society some six years ago, to do away with free clinics and substitute an interest on the part of the practicing physician in preventive as well as curative medicine. If we could have 1,500 health centers in Detroit instead of the few which the health department could support, how much better it would be for the public. Instead of going to free clinics, our people would go to the office of one of the cooperating physicians for prophylactic services; immunization against diphtheria, vaccination for smallpox, the annual health examination, the early diagnosis of tuberculosis and cancer. There are other diseases which are not primarily the concern of the health department since they are not communicable, but offer problems in which the health department is becoming more and more interested because of the high mortality.

A program of diphtheria prevention was agreed upon as our first objective. We closed all our free immunization clinics. There has been no free clinic for diphtheria protection for over three years, and yet we feel sure that there is no large city in the United States which by actual count has a higher percentage of its children protected against diphtheria. All the immunizations are given in the office of the family physician, or the cooperating physician. We have an agreement with each individual physician that if on certain days at certain hours the parent presents himself with the child, the doctor will give a definite service for a certain specified fee. The fee was set

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27–30, 1932.

by the medical society. If the parent comes to the office at this hour toxin-antitoxin or toxoid is given for $1.00 a dose, $3.00 for three doses, or for nothing if in the physician's judgment the parent cannot pay. The health department reimburses the physician for those who cannot afford to pay, at the rate of 50¢ per dose, or $1.50 for three doses. We also pay $1.00 for the Schick test.

This plan has functioned for three years, and we now have 77 per cent of our school children and 43 per cent of our preschool children immunized against diphtheria, without free clinics. Not a dose of toxin-antitoxin has been given by the health department. One of the criticisms of the plan has been that of expense. Some health officers say that it is too expensive, but let me set you at ease in that regard. In no year has the whole program, including sums paid physicians plus the expenditure for the immunizing agent, equalled the previous cost of treating cases of diphtheria in our own hospital. The diphtheria death rate has been cut in four. During the past three years the physicians of Detroit have lost $60,000.00 because of the reduction in the diphtheria death rate. During these same three years the physicians have been paid either by parents or by the Health Department $325,000.00 for their services. In other words, preventive medicine has paid the physician more than curative medicine in the ratio of five to one. The average cost of treating a case of diphtheria is $35.00. The average cost of prevention is $3.00. Therefore, the parent has gained in the ratio of more than ten to one. We have, above all things, created an atmosphere, a thought of preventive medicine in the office of the average medical practitioner, so that the doctor is now thinking in terms of preventive medicine and not merely in terms of curative medicine.

We have made no particular effort to secure vaccination against smallpox other than to encourage it wherever possible. The percentage of preschool children vaccinated against smallpox has increased from 22 to 43. There have been no funds to pay the physician for this service. He should be paid. We believe it is a basic and important principle that a physician should be paid for his services. In the past, physicians have done too much for nothing. It is largely their own fault. You do not find the legal profession doing likewise. If a man without funds is caught in the toils of the law, the court appoints a lawyer and the state pays the lawyer; but if a doctor takes care of an indigent case the doctor usually is not paid. We feel that it is important that the physician should be paid at least a small honorarium for his service.

Last May, we made a beginning in applying the plan of medical participation to the control of tuberculosis. The most important tools for finding the early case of childhood tuberculosis are the tuberculin test and roentgen examination of the chest.

Year after year we have urged, in our annual tuberculosis case finding campaign, that parents take their children to the family physician. At the same time we have had free clinics in public buildings, and tuberculin surveys in the public schools. Last spring we decided to follow our other program, and during the months of April and May we urged, through a very definite program of education, that the parents take their children not to a clinic but to the family physician for a tuberculin test. During those two months, 5,000 parents in Detroit took their children of school age to their family physician for the tuberculin test.

We had built up a group of cooperating physicians. We had correlated the work with the local roentgen society so that the roentgenologists cooperated. We do not know, unfortunately, how many roentgen examinations were made. Our record system was incomplete. We report these results merely as a beginning, as a healthy indication that you can educate the public to the viewpoint of going to the physician for a preventive service in tuberculosis, for a tuberculin test, and for a roentgen examination.

We must mention one important part of our program, that is, our postgraduate course for physicians. When we started our diphtheria work we found some physicians who did not know the difference between toxin-antitoxin and antitoxin. In fact, a few gave antitoxin for immunization. We instituted a postgraduate course in communicable diseases. During the first year one-third of the membership of the county medical society attended a course of instruction in communicable disease control, a course consisting of an hour's lecture given once a week. The interest was gratifying. Last year a similar course in tuberculosis case finding was conducted. It is essential that the medical profession be prepared before the public is prepared.

We are reminded of an interview with a physician who visited the Health Department and who did not believe in giving antitoxin in the treatment of diphtheria. After arguing for some time and offering a series of laboratory experiments, we finally inquired in despair, "Where in the world did you graduate in medicine?" He said, "It might interest you to know that I was a student of your father's at the University of Michigan." We further inquired, "In what year did you graduate?" He replied, "I graduated in 1890."

The only trouble with this gentleman was that he graduated two years before Roux gave the world antitoxin, and he was still practicing the medicine of the vintage of 1890. Unfortunately, there are a few physicians of that character.

Those physicians who are wont to attend medical meetings with regularity will cooperate in a program of preventive medicine, but the physician who must be reached is the one who never goes to any medical meeting. Consequently, we employed a medical coordinator who went around and visited such physicians in their own offices and prepared them to practice preventive medicine.

We believe that this program of medical participation in public health work is applicable to tuberculosis control. We would never subscribe to a program of drastic revolutionary character. We do, however, subscribe to a program of education and evolution whereby the need for the free clinic will be largely minimized. Clinics serve a useful purpose as teaching centers and as a means of demonstrating the efficacy of control procedure. We believe that much of the service now rendered to indigent patients in clinics and dispensaries can gradually be transferred to the prepared physician in his own office.

THE VALUE OF THE ROENTGEN RAY IN APPARENTLY HEALTHY CHILDREN OF SCHOOL AGE*

By D. S. BRACHMAN, M.D.
DETROIT, MICHIGAN

THE case-finding program, as described to you by Dr. Vaughan, can be divided into two parts: first, the diagnosis of tuberculosis in patients having symptoms, with examination of contacts; second, work on a large scale on the apparently healthy. Our program for case finding is one that deals entirely with the latter group. It is, therefore, supplementary to and not a substitute for the usual method employed until recently.

Some very interesting facts were elicited in a study of 35,000 school children, of which 9,000 were of high school age. In one of the high schools we found 14 cases of adult type tuberculosis, which was 1 per cent of the enrollment. General development was good or fair in all but 4 cases. Definite symptoms of disease were found in only 3, a fourth student having a "cold" for one week only. As to physical signs, in only 2 was the evidence of disease definitely apparent, while in 2 others there were slight signs ordinarily calling for further investigation. Another outstanding fact elicited was that only one of the 14 students had a contact history. Thus, in the previously employed program of tuberculosis prevention only one of the 14 children would have been investigated.

The findings in this group, as well as those in the other schools, were then divided according to their various houses or home rooms, as they are often called. It is according to such a classification chiefly that contact can be considered, for in all other groupings the contact is comparatively slight and particularly complicated, there being as many as 100 class rooms in one of the schools studied.

Going further into those 14 cases there was one girl, sixteen years of age, who had a very markedly advanced lesion in the left lung; in fact, the whole lung was tuberculous. She was well nourished and developed. She played on two of the school teams, and did not have the faintest idea there was anything the matter with her. In her case, of course, the physical examination showed very definite pathological signs.

Taking some 24 rooms that were investigated in these high schools we did not find more than 2 in any home room except the one in which this girl was found, and in which 7 cases of adult type disease were discovered. After careful consideration of all factors, we came to the definite conclusion that one girl gave tuberculosis to at least 5 other girls in her home room. In other words, we are faced today with definite information that in the school systems of the various large cities where large numbers of children congregate day after day, we will find a definite source of contact, an innocent source, if you like, because not more than 3 of those 14 children had any idea they were ill and, therefore, they could not have taken the proper care of themselves.

The results of the investigation of the 35,000 children showed that adult type tuberculosis occurred only occasionally in the grade school children. Taking all the high school children, however, the general average was 0.5 per cent, or one in 200; 4.9 per cent had childhood type tuberculosis, and 1.5 per cent were suspects.

We suggest where work is being done in tuberculosis among the apparently healthy children, that the initial program be started with the high school age. Though the percentage of adult type in the lower grades is very low, the percentage of childhood type is rather high, and because the childhood type is the potential adult type of high

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27–30, 1932.

school or later years, it is strongly advisable where finances make it possible that all the school enrollment be included in the investigation.

All the open-air schools in Detroit are used for childhood type tuberculosis. It is apparent that in that way the physicians and the Department of Health can carefully check up on this group, and as found necessary, exclude them from school, whereas if they were all excluded a large number would be unnecessarily hampered and certainly their parents would be frightened.

All children should be tuberculin tested and the reactors examined roentgenologically. We feel definitely satisfied that in no other way is it possible to diagnose all of the adult type tuberculosis at its beginning. No other method answers the purpose. We have found that out very conclusively.

In closing, I would like to suggest one thing. Before you make a final diagnosis even where you see a definite childhood type and what looks like an infiltration of the lung, I suggest that you re-examine the child by roentgen ray, if the lesion is very small, in approximately ten days to two weeks, because we have discovered that what apparently looks like a definite adult type involvement sometimes turns out to be a pneumonic process. I am certain all of you run into that but because of the severity of the after-treatment following the diagnosis of tuberculosis, we feel it is advisable not to take the diagnosis by roentgen ray too lightly. In our discussions with the physicians and the health workers, we always emphasize that the roentgenologist should be given an opportunity to check up if necessary; that when he desires to check up it is for the interest of the patient rather than, as some think, a matter of personal gain.

Vol. XXX, No. 3

THE IMPORTANCE OF THE ROENTGEN EXAMINATION IN THE MODERN TREATMENT OF PULMONARY TUBERCULOSIS*

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IT IS now quite generally recognized that the roentgen ray is the most accurate means at our command for the diagnosis of pulmonary lesions of all sorts and pulmonary tuberculosis in particular. It may be, however, that the place of the roentgen ray in following the course of disease and the progress of treatment in pulmonary tuberculosis is not so well understood.

It is not sufficient simply to make a diagnosis of pulmonary tuberculosis, any more than it is enough to tell the patient that he needs rest, and let diagnosis and treatment go at that. Pulmonary tuberculosis must be amplified in its diagnosis both upon a quantitative and a qualitative basis. To explain what is meant: A quantitative diagnosis must indicate the part of the lung involved and the extent of the involvement, which may well be put into the terms of the usual classification of minimal, moderately advanced, far advanced, and childhood type. The next step, however, may not be so readily apparent, namely, the making of a qualitative diagnosis, by which is meant a more careful analysis of the type of lesion found, as to whether it is exudative, productive, or a mixed lesion with both exudative and productive elements present. If cavities are present, the qualitative diagnosis should include a description not only of their size and location, but also their type. Pinner has made a very useful classification for this purpose which lends itself to practical application. In this classification, there are three types: (1) the small, multiple cavities in densely infiltrated parenchyma, frequently referred to as "moth eaten," (2) round or oval, thin-walled cavities and (3) irregularly shaped cavities with thick walls.

Such a diagnosis as that just outlined depends on the roentgen ray and can be accurately made only with its aid. Having made such a diagnosis, it is possible then to determine the proper measures of treatment to employ, and to follow the course of treatment, noting the success attained and whether or not it may be necessary to add other procedures.

The treatment of pulmonary tuberculosis is still based upon the fundamental concept that rest to the injured or diseased part is the best aid to healing, but whereas a few years ago rest in bed was the only means generally employed for this purpose, more recently collapse therapy has been added to the armamentarium of the phthisiotherapist. The addition of this means of treatment is the biggest single advance yet made in the control of tuberculosis. With the aid of collapse therapy it is possible to treat the individual case more successfully and restore the patient to health. The prompt closure of cavities, and resultant cutting off of sputum containing tubercle bacilli, is a most effective check to the spread of the infection in the community.

Collapse therapy is the general term applied to such procedures as paralysis of the diaphragm produced by surgery upon the phrenic nerve, artificial pneumothorax, and thoracoplastic surgery, together with several additional procedures less widely employed but all depending upon the principle of either temporarily or permanently relaxing the lung by lessening the space it must occupy. Actual compression of the lung is used at times but far more frequently simple relaxation, by allowing collapse of the expanded lung, without compression, is employed. Any procedure pro-

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ducing either simple relaxation or actual compression comes under the general heading of collapse therapy.

Minimal pulmonary tuberculosis, without some evidence of cavity formation present in the lung, does not account for a very large number of cases among all those presenting themselves for treatment. While it is most desirable to discover the presence of pulmonary tuberculosis before cavitation has occurred, still the fact remains that most patients when discovered to have the disease, do have evidence of cavity formation.

It is not necessary to point out, other than to mention, that the presence of cavity in the lung is of grave significance. Graef in 1921 made the statement that the presence of cavity in pulmonary tuberculosis sounded the death-knell of the bearer. In the main, this is a pronouncement open to little question. However, if cavities can be closed, it is now known that recovery can be made in a large number of cases. Collapse therapy offers such a means of controlling the cavity and saving the patient.

Another factor that is not often considered is that cavity formation is not a late manifestation, but occurs early in the disease—indeed it may be said to be an acute process. It has been found, for instance, in a study at the William H. Maybury Sanatorium, that in a group of 119 patients who had an acute onset of their disease and in whom the symptoms had been present for six months or less, there were 86, or 72.2 per cent, who had evidence of cavity formation.

It was further noted that in similar groups of longer duration, where the onset was acute, the percentage of cavity-bearers did not increase, but remained essentially the same, regardless of duration of the disease when first seen. (A table from this study will more clearly illustrate this point.)

It is true that cavities do heal spontaneously under a simple bed rest regimen, but it is also true that this favorable outcome is so unusual as to be remarkable. In fact, it is recognized by most of those who have studied tuberculosis carefully that most cavities show little tendency to close spontaneously. On the other hand, the addition of collapse therapy will close many cavities promptly, and start others on a slow but steady progress toward closure. The fact that it can be demonstrated that cavities will close promptly after collapse measures are employed is in itself sufficient reason for employing these procedures promptly, without taking the risk of the cavity becoming larger and more serious because of older and more rigid walls.

Realizing, then, the seriousness of cavitation and the rapidity with which cavities may form, there need be no other argument brought out for the prompt institution of collapse therapy for the control of this menace to the patient.

It has repeatedly been shown that physi-

RELATION OF COURSE OF DISEASE TO PRESENCE OF CAVITIES AND DURATION OF SYMPTOMS

Duration of Symptoms	Sudden Onset			Insidious Course		
	No. of Patients	Cavities Present		No. of Patients	Cavities Present	
		No.	Per cent		No.	Per cent
6 months and less	119	86	72.2	31	12	38.7
More than 6 mo. to 2 yr.	134	93	70.0	45	29	64.4
More than 2 to 5 yr.	38	26	68.4	27	13	48.7
More than 5 yr.	25	19	76.0	15	9	60.0
Total	316	224	70.8	118	63	53.4
Average duration of symptoms		1.63 years			2.64 years	

cal examination of the chest will not give the information desired, and that only by roentgen examination can the lesion be accurately enough visualized to be the basis for establishing proper collapse measures. Again, serial roentgenograms taken at suitable intervals will determine the effectiveness of the treatment instituted and whether any additional procedure is needed to produce the proper collapse. If, for instance, it is found that there is a recent exudative lesion with multiple small cavities present, and limited to less than moderately advanced extent in one lung, a phrenicectomy may give sufficient collapse to bring about healing. If closure of the cavities and negative sputum do not result promptly—say in three to four months—which condition, of course, can be determined only by taking a roentgenogram, it will be necessary to add pneumothorax to bring about more complete collapse. It is always well to corroborate the completeness of the collapse by the absence of tubercle bacilli in the sputum for, if the roentgenogram indicates no cavity and the sputum is negative for tubercle bacilli after careful search, the evidence is well established that closure has occurred.

Artificial pneumothorax, to be successfully carried out, must be carefully followed with suitable visualization. A film should be taken every two or three months. Furthermore, it is most advisable to use the roentgenoscope before and after each refill, which will make for greater safety and will acquaint the operator at all times with just how satisfactory the collapse is, whether fluid has formed, the space is being lost, or if adhesions may be defeating a successful result.

The course of pneumothorax treatment must be watched most carefully, for, in addition to those complications already mentioned, shifting mediastinum and the effects of various pressures on the degree of collapse must be observed. By careful roentgen examination it can be determined whether adhesions, when present, should be cut to bring about better collapse. It will also be necessary to determine the adhesions that it may be possible to cut, and from their size to judge how best to cut them: by the Jacobeus method of cautery, with thoracoscopic observation; or the direct observation method of O'Brien, in which clamping and cutting is done through a small incision in the costal periosteum after resecting a small portion of rib. These and other modifications of pneumothorax must be undertaken only after most careful visualization with the roentgen film and the fluoroscope.

It would be impossible to carry on such treatment satisfactorily without the aid of the roentgen ray. It is true that artificial pneumothorax was employed as a therapeutic measure in pulmonary tuberculosis before visualization by the roentgen ray came into use but, while there were some striking results, the inability of the operator to know with any exactness the state of the lungs, resulted in this form of treatment being little used and even abandoned for several years. Murphy and Tice used artificial pneumothorax in Chicago in the '90's but gave it up even though they felt its was a valuable measure. With the widespread use of the roentgen ray which has taken place in more recent years, pneumothorax has come into its true place as a most valuable aid in producing arrest in pulmonary tuberculosis.

The roentgen ray is important in deciding upon various thoracoplasty procedures, to learn as exactly as possible the condition of the lung to be collapsed in order to determine the amount of surgery to employ. It is also necessary to know the condition and functioning capacity of the better lung as deduced from the roentgenogram.

It must be readily apparent that to attempt to follow the course of treatment with any form of therapy in pulmonary tuberculosis by physical examination, without the roentgen ray, would be out of the question. The better understanding of the nature of pulmonary tuberculosis, and the ability to visualize the lesions and what may happen to them under treatment, made possible by roentgenology, has allowed the

use of collapse therapy. Indeed the roentgen ray has made collapse therapy possible and, instead of the cavity being the deathknell of its bearer, many are saved by prompt application of one or more of the collapse measures available.

This symposium surely will make clear the fact that collapse therapy is the biggest advance yet made in the treatment of pulmonary tuberculosis, and it is readily apparent that its success is based on careful use of the roentgen ray both for complete diagnosis and the check on results obtained during the course of treatment.

SUMMARY

1. The roentgen examination provides the information for a quantitative and qualitative diagnosis in pulmonary tuberculosis.

2. The cavity in tuberculosis signifies a most serious prognosis.

3. Collapse therapy will serve to close many cavities and thereby convert a grave prognosis into a favorable one.

4. The proper application of collapse therapy depends upon accurate visualization by means of the roentgen examination.

Vol. XXX, No. 3

ARTIFICAL PNEUMOTHORAX IN A GROUP OF CASES OF PULMONARY TUBERCULOSIS FORMERLY LOOKED UPON AS HOPELESS*

By RICHARD MORGAN, M.D.
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AN EXTENSIVE literature dealing with artificial pneumothorax has accumulated in the past few years. The use of the method in the treatment of pulmonary tuberculosis long ago ceased to be in any way experimental and is today accepted, as Rist of Paris, has stated, as the greatest advance in the treatment of tuberculosis since the advent of the so-called rest cure. Much has been written concerning the technique of the procedure. It will be unnecessary to mention that in this paper. The indications for instituting a pneumothorax would make a long chapter and cannot be covered here. The chief purpose of this paper is to briefly point out its applicability in quite a large group of cases in the past generally looked upon as hopeless and for whom no treatment other than prolonged and generally futile bed rest was prescribed.

Most of these cases are moderately or far advanced with disease predominantly in one lung; cavity or cavities are recognized in the lesion and have been responsible for bronchogenic spreads into the opposite lung, where already there may be evidence of excavation. Are we to deny this large group a chance of recovery, or at least marked improvement? We know full well the fate of most patients who have progressed to the stage of cavity formation—continuously positive sputum with resulting bronchogenic spread of disease into the formerly uninvolved lung.

Our experience in the treatment of this general class has been so encouraging that we have come to feel that most of them should be given a chance through some form of collapse therapy.

We may do a pneumothorax on the most advanced side, watching the lesion in the opposite lung with an idea of instituting treatment promptly if needed; often we will note a prompt and favorable clearing of the lesion in the contralateral lung which continues to the point of satisfactory fibrosis of the lesion. If the lesion appears to progress a pneumothorax may be begun at once, or if the lesion is not too advanced a temporary paralysis of the diaphragm on that side may be produced, holding pneumothorax in reserve for further chance to observe the behavior of the disease. It will happen in some cases that a quite definite cavity in the contralateral lung will be seen to close soon after instituting a collapse on the opposite side.

We were for many years warned about establishing a collapse where a lesion could be recognized in the contralateral lung. We took it for granted that the contralateral lung would suffer from the added work imposed upon it while the diseased lung was under collapse treatment. Gradually as we have attempted treatment in cases which were bilateral we have been impressed by the manner in which lesions in the opposite lung cleared under treatment of the more involved side. We were inclined years ago to ascribe this to the general improvement in the condition of the patient brought about by closing up the badly diseased lung. Today we are inclined to a very different explanation. It is not the occasional case that demonstrates a clearing of the lesion in the contralateral lung. In our experience it is seen to result in the large majority of them. The result is that a formerly hopeless group are now being offered treatment which was in years past denied them.

Confronted with bilateral disease we have two chief factors to consider. First, is there enough normal lung tissue to warrant

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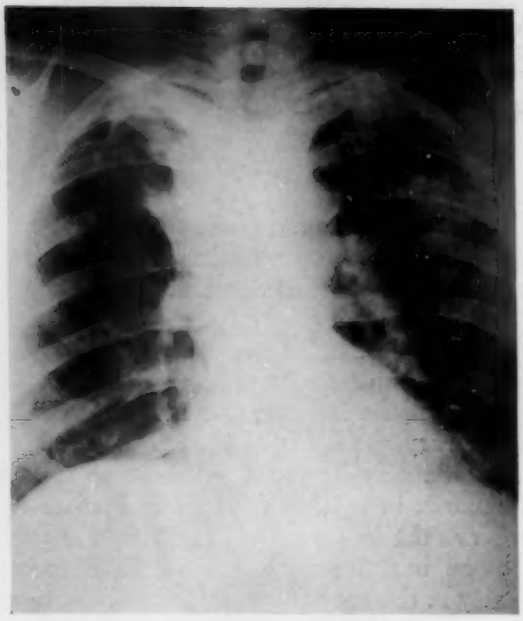

Fig. 1. Case 1. Adult male, aged forty, admitted with moderately severe hemoptysis of two weeks' duration, bleeding from left lung; controlled by pneumothorax.

establishing a bilateral pneumothorax? Second, is our patient so ill that he is unlikely to benefit by treatment? A bilateral case running fever, exceedingly toxic and suffering from complicating enteritis or laryngitis, or both, is not likely to respond favorably. Is there noticeable shortness of breath, dyspnea, emphysema? If so, treatment will probably aggravate rather than improve these symptoms. Exceptions even to this could be illustrated. However, if there be sufficient normal lung to enable the patient to carry on, and if he has demonstrated that his disease is being held in check in some degree, we can offer him collapse therapy. If the lesion on one side is advanced and on the other of moderate extent and without clear cut or large cavity, we feel that we can collapse the more advanced side, watching the progress or retrogression of the lession in the less involved lung. At any time if conditions warrant we must be ready to institute treatment on the opposite side.

The most reasonable explanation of the favorable effect of collapse treatment noted to take place in the contralateral lung is the lessening of that half of the thorax as a result of a shifting mediastinum. We have seen this happen in a few cases to a surprising extent early in treatment, bringing about so much relaxation of the contralateral lung that the lesion here was markedly favorably influenced in the first few weeks of treatment.

If there is not much choice in the two sides in respect to extent of lesion, degree of cavitation, etc., it will usually be decided to begin a bilateral collapse at once. More times than not one lung *is much more involved than the other*, and in such a case we are apt to begin our collapse on the more advanced side, withholding treatment of the contralateral lung for a month or so to note whether the improvement in this lung will be sufficient to obviate the necessity of a pneumothorax on this side.

We may have a patient with bilateral disease who is bleeding from a more recent spreading lesion opposite from the old

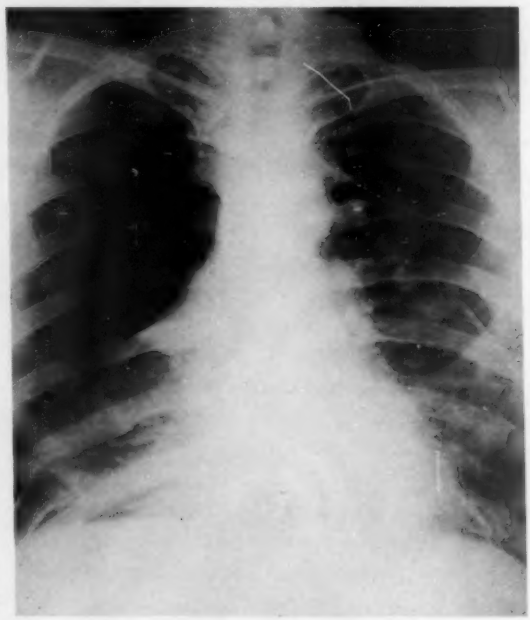

Fig. 2. Case 1. Showing complete control of lesions in both lungs with closure of large cavity in right apex from which there had been a spread of the disease into left lung.

fibrocavernous involvement. In such a case we may be obliged to control the acute symptoms, particularly the hemoptysis, by collapse of this lung. At a later date we can then direct treatment to the old excavated lesion in the opposite lung (see Figs. 1 and 2). We have examples of the benefit of this plan of procedure.

It seems quite proper to mention in this paper a very necessary part of the management of many pneumothorax cases; namely

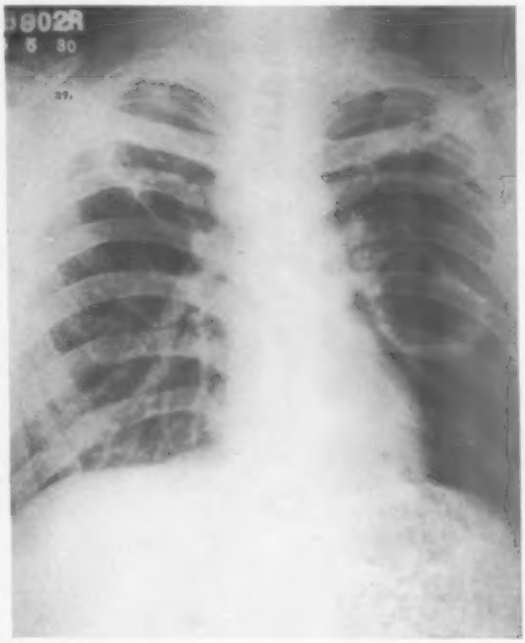

Fig. 3. Case II. Middle aged male, with history of disease for several years, old fibrotic lesion in right apex, with more recent disease in middle of left lung with large cavity; positive sputum.

the adding of a phrenicectomy to assist in the closure of the cavity. Early in some cases, especially if there is a history of *recent* hemoptysis, we will note that as we proceed with collapse of the lung we will tend to promote hemoptysis. We have thought that the explanation was a pull on adhesions tending to hold open rather than close a cavity.

In several cases the hemoptysis occurred promptly after each treatment, and the addition of paralysis of the diaphragm on

Fig. 4. Case II. Same case after closure of cavity by means of artificial pneumothorax. Phrenic paralysis. Sputum negative for past two years.

the treated side served to relax the adhesions to a degree permitting of suitable splinting of the bleeding area.

In a satisfactory collapse it is expected that the sputum will become negative; a

Fig. 5. Case III. Young adult, married female, with large cavity in left upper lobe; positive sputum.

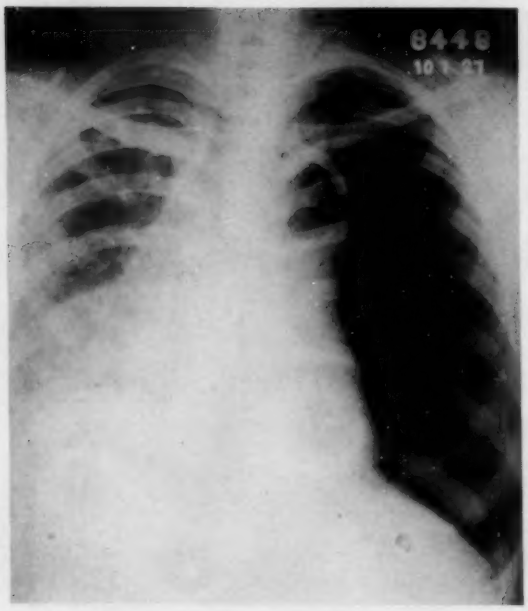

Fig. 6. Case III. Same case with very complete collapse of the lung but cavity still held open and resisting high positive pressures.

persistently *positive* sputum seems reasonable evidence of incomplete closure of cavity. The great majority of our pneumothorax cases exhibit a negative sputum within three or four months of the beginning of treatment. If they do not, it is usually because of adhesions holding cavities open, and in such cases we do not hesitate to add a phrenicectomy. The result in many of these is most gratifying and seems sufficient evidence in favor of procedure.

Should we fail to accomplish sufficient relaxation of the adhesions which are preventing proper collapse there is still more that we can offer the patient. We may by either the so-called closed or the open method cauterize the pleural adhesions and thereby permit the cavity to close.

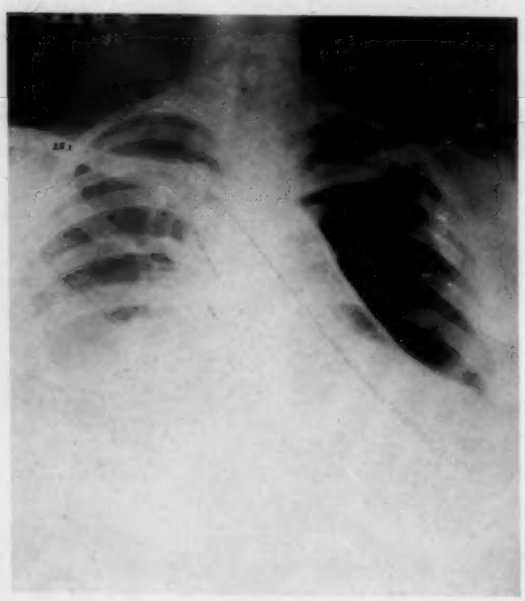

Fig. 7. Case III. Same case approximately two months after phrenicectomy was added. Cavity closed.

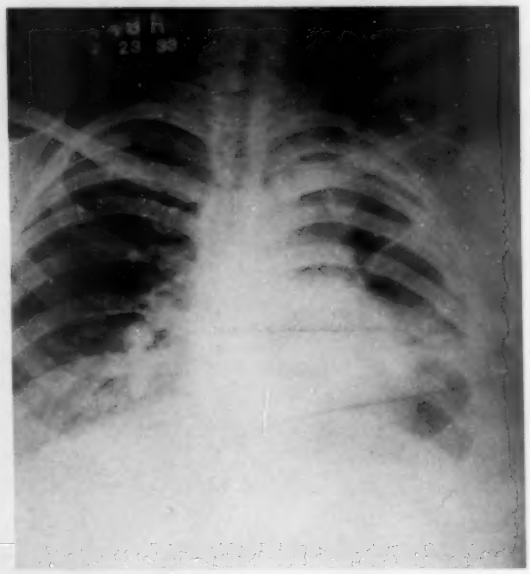

Fig. 8. Case III. After five years of treatment; re-expanded; no cavity; no sputum. Patient has gone through normal pregnancy during treatment.

The methods mentioned in this brief paper are applicable to either unilateral or bilateral cases and will be dictated by the peculiar situations as they arise.

It may be necessary to abandon a pneumothorax on one side and permit this lung to re-expand with the protection afforded by a phrenicectomy. We may at any time in a previously unilateral case be obliged to begin artificial pneumothorax on the opposite side if a spread occurs in this lung. It

may be required that we aspirate fluid, perhaps repeatedly from one or both sides, but we should not be too easily discouraged because of these necessities.

We have one most interesting case, that of a young girl who came to us with an abandoned pneumothorax on the right side (see Figs. 9, 10 and 11). The pleural cavity here was almost completely filled by a clear, sterile fluid, but in the opposite lung had occurred a severe spread throughout the upper third or one-half with evidence of cavity

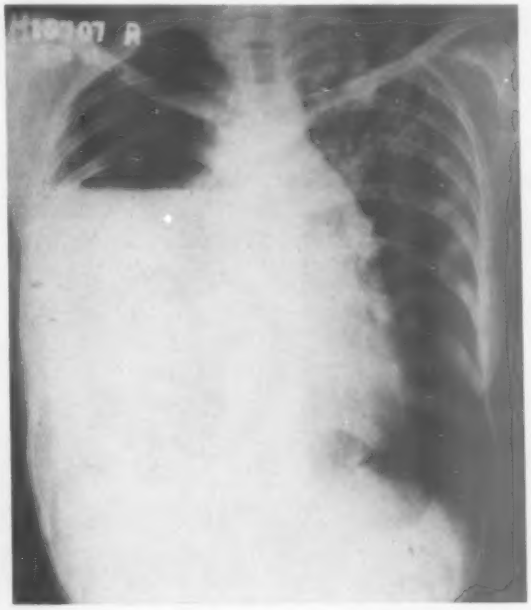

Fig. 9. Case iv. School girl, aged sixteen, admitted with pneumothorax on right, fluid requiring frequent aspiration. Recent excavating disease on the left; considered a hopeless case.

developing. At first it was felt that the outlook was too hopeless to warrant further collapse therapy, but with the advent of streaked sputum we determined to do something. We repeatedly aspirated the fluid on the treated side in order that this lung might re-expand and function should the emergency of real hemoptysis arise in the contralateral lung. As the lung re-expanded its appearance was reasonably satisfactory, and fortunately so, for soon serious bleeding took place in the opposite lung requiring pneumothorax for control.

Fig. 10. Case iv. Same case after repeated withdrawal of fluid from the right to permit re-expansion of lung in order that a pneumothorax might be established on the opposite side. Collapse is limited by adhesions and cavity still open.

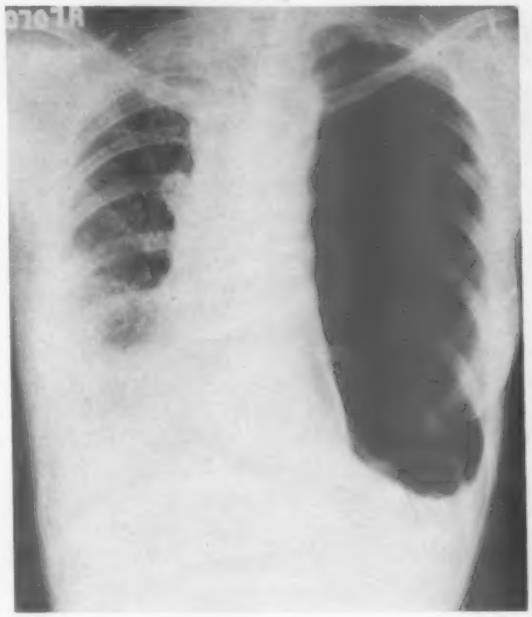

Fig. 11. Case iv. Same case within forty-eight hours after extrapleural pneumolysis. Cavity closed. Cough and sputum completely eliminated.

The collapse here was continued after the emergency had passed, but was soon complicated by large amounts of fluid requiring repeated aspiration. The fluid finally ceased recurring, but we were confronted by several adhesions which prevented closure of a rather large cavity. The sputum continued to be positive, and therefore a phrenicectomy was added in the hope that this would effect closure. Failing in this we decided to sever the adhesions by cauterization and almost at once found the cavity practically closed. Four days after operation the patient stopped coughing and raising sputum.

It is cases of this sort that encourage us to *do something* rather than assign these patients to the uncertainty of bed rest alone. If nothing is done they are in most cases doomed to suffer an early death. If we attempt treatment we will probably bring about a fair recovery in a surprising number of otherwise hopeless cases.

We recognize the additional hazards imposed by bilateral therapy but feel that they are outweighed by the hazards of the disease itself. A spontaneous pneumothorax superimposed upon a therapeutic collapse may be so severe as to cause death. This has been reported in a few instances. Fluid may complicate one or both sides, but as a rule can be handled without difficulty. The cardiac efficiency must be carefully watched and dyspnea given our serious attention. In a patient already dyspneic, it is doubtful whether we should even begin *bilateral* collapse. These cases require most painstaking observation, and yet a large number will reward us for such effort on their behalf. It seems better to offer many of these patients active treatment rather than to subject them to months and months, or perhaps years, of progressing invalidism finally terminating, as it will in most, with death.

Vol. XXX, No. 3

COLLAPSE THERAPY IN EARLY MINIMAL LESIONS OF PULMONARY TUBERCULOSIS*

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THERE could be no place more appropriate for a treatise on the surgical treatment of pulmonary tuberculosis than a meeting of roentgenologists since it is almost entirely upon roentgenological findings that collapse therapy is based. Symptomology, laboratory work, and occasionally the stethoscope, are essential adjuncts, but as the successful treatment of this disease depends, to a large extent, on the detection of early, minimal lesions, as well as on the knowledge of the extent and character of all lesions, we must look to the roentgen ray for our information. No other method of examination will give the necessary data upon which to base intelligent treatment.

Sampson and Brown state that, in early minimal lesions, the stethoscope, in their hands, failed to detect pathology in about 40 per cent of patients, while roentgen examination finds almost 100 per cent. Therefore, if we wait until stethoscopic examination reveals to us that pulmonary disease is present, a large percentage of our patients will be in the moderately or far advanced groups before treatment is instituted. Also, without the assistance of the roentgen ray the character of the lesions, the size of the cavities, and other necessary information will not be available.

I have for years advocated some form of collapse therapy in almost all patients with pulmonary tuberculosis as soon as active disease is discovered unless, of course, there are contraindications to its use. There can be only two exceptions to this rule, the one being those patients who have such early, minimal lesions that are improving or that may be expected to improve under bed rest alone; the other is that group in which the disease is so far advanced and extensive that the procedures may appear to be futile.

Today, almost everyone who has kept abreast of the startling advances made in the surgical treatment of pulmonary tuberculosis agrees that collapse therapy should be resorted to, when possible, in all those patients in whom, after a variable length of time, it appears that the disease will not be controlled by the negative form of treatment consisting of bed rest, hygienic, and dietetic measures alone. There is still, however, much disagreement as to the advisability of instituting active surgical treatment in early, minimal lesions as soon as they are discovered. It is with this question that my paper will deal.

In this group of patients, we have three problems to consider: (1) Will the individual, unaided by some form of collapse therapy, be certain of complete and permanent healing? (2) Will the addition of collapse therapy make healing more certain, and accomplish it in a shorter period of time? (3) Will the addition of this treatment be detrimental to the patient now or in the future?

The answer to the first two questions should be obvious. No patient is certain of overcoming pulmonary tuberculosis regardless of the extent of the disease or the method of treatment. In almost all cases, if the patient does become well, it will be principally because of the rest afforded the lesion. The wonder is that anyone ever recovers from this disease unaided by some form of surgical treatment. The constant, interminable motions of respiration certainly do not tend to afford rest sufficient to allow healing. There is, moreover, no natural tendency for cavities to heal. The lung is normally under tension, and is stretched to fill the thoracic cage. Each inspiration tends to stretch it still farther which action pulls the cavity walls farther apart, and retards healing.

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27-30, 1932.

The application of any form of collapse therapy is made in the attempt to overcome these untoward actions by reducing the size of the thoracic cage, or the space in which the lung moves, in order to allow sufficient relaxation of the stretched lung to cause approximation of cavity walls, and enough restriction of motion to allow healing. The various procedures accomplish this to varying degrees, and do so, of course, regardless of the extent of the lesion, and must, therefore, facilitate healing in a shorter time in minimal as well as in advanced lesions.

We know that as long as cavities remain open, and sputum continues to be positive for tubercle bacilli, the patient is a menace to himself and all others with whom he comes in contact. These conditions, therefore, should both be eliminated as rapidly as possible.

What, then, is the excuse for withholding this form of treatment? In this group, the only argument advanced is that some patients became well before it was used—surely a slender thread upon which to cling. That some few did survive can be of but little interest to the thousands of relatives of those who did not recover, and to those who contracted the disease themselves because of needless and protracted exposure to the survivors.

Of what value are the tireless efforts of health authorities and others to induce patients to be examined frequently in order that their disease may be detected early if we fail to employ all the measures at our command to overcome this disease, when it is found, in the shortest possible time? This element of time is of serious importance both to the individual and to the community. In our present economic condition, neither the patient nor local and state agencies are financially able or willing to pay for expensive hospitalization longer then is necessary. Moreover, it is our duty always to get patients well as quickly as possible in order that they may return to the community and their families and again become self-supporting.

It is impossible to judge accurately the fate of patients with early, minimal lesions under the old regimen of treatment. During the early years of sanatorium care, before the use of the roentgen ray, no accurate diagnosis as to the extent of the lesions could be made, and it is probable that few patients in this class applied for treatment. The results of treatment also were verified by stethoscopic examination which makes this information of little value. A careful search of the literature fails to reveal any figures of real significance.

Probably one of the most interesting surveys on the results of bed rest treatment alone is that made recently by Dr. Ray Morgan of Westfield State Sanatorium in Massachusetts. He has made a careful check of all the children under the age of twenty-one who have undergone treatment at that institution. Of 200 patients treated between the years 1910 and 1920, 77 died under treatment, 123 were discharged and, of this number, 78 are now dead, making the total number of deaths 155. In another group of 198 patients treated between the years 1920 to 1927, 62 have died. In this group, there were 49 patients with cavitation, and of this number, 45 have died, and 4 are living, one of whom is in fair condition.

Zacks of Boston reports a group of 110 children whose lesions were discovered through routine school examination. After four and one-half years of treatment, 25 per cent were dead, 50 per cent were progressive, and the remainder were stationary or missing.

Barnes of Wallum Lake has published a survey of over 1,400 patients who have been treated at his sanatorium for cavitation and sputum positive for tubercle bacilli. Of his patients 95.4 per cent were dead within five years. None of the patients referred to in these surveys received the assistance of collapse therapy. Surely this is not a very heartening report for those who still refrain from the early employment of surgical treatment.

In contrast to these figures, we may cite the survey made recently at the William H. Maybury Sanatorium at Northville, Michigan. In the year 1927 when collapse therapy was first begun at that institution, their mortality rate was 25.8 per cent. During the year 1931, under the influence of early case findings and collapse therapy, the mortality rate had decreased to 10 per cent. At the same institution, those discharged as apparently arrested in 1927 were only 8.1 per cent while in 1931, the number so discharged had reached the startling figure of 34.1 per cent. It must also be remembered that in their figures of the last few years, there necessarily were included many of the old, chronic invalids who had been carried over, and also many patients who could have been discharged as arrested, but who were kept at the institution because of economic conditions since they had neither homes nor work to which to go.

In the year 1930 at the same institution, a comparison was attempted between patients treated with bed rest alone and those who received the assistance of phrenicectomy. In the cases compared, the extent and character of the disease were as nearly alike as was possible to determine. It was found that in those patients who received bed rest alone, cavities closed in 14 per cent, and decreased in size in 25 per cent of cases. Cavities increased in size, however, under this form of treatment, in 61 per cent, and cavities which had closed reopened in 42 per cent. In none of these patients did the sputum become negative. In that group in which only the assistance allowed by phrenicectomy was given, the cavities closed in 49 per cent, and decreased in size in 35 per cent. Cavities increased in size in only 7 per cent, while none of the cavities which had closed reopened. In 45.8 per cent of these patients, the sputum which had previously been positive for tubercle bacilli became negative in 45.8 per cent.

In 1930, I published a paper on the results of phrenicectomy in 500 patients, and reported that 52.2 per cent of those patients who had sputum positive for tubercle bacilli before operation became negative following it. In this series, those patients with minimal disease and only moth-eaten cavities obtained this result in 90 per cent. Phrenicectomy is the simplest form of collapse therapy, and also is the least effective, but such figures show the efficacy of even this small amount of assistance to nature's attempt at healing. The results following the use of artificial pneumothorax therapy, which gives the greatest amount of assistance to these patients, is, of course, still more startling.

With those who argue that it is better to get well without these procedures, if possible, one could not disagree were it not for the insurmountable fact that, with our present knowledge of this disease, we are unable to determine whether or not the patient can overcome it without this assistance. If we make the experiment, many patients who cannot will certainly be lost in the hope that some few may be able to do so. Also the majority of those in whom the disease becomes arrested without this aid, require it anyway to maintain the healing.

It is sometimes said that as long as a patient is under treatment at an institution the lesion can be watched, and if it is not healing favorably, these procedures may then be applied. In theory, this attitude might seem sound, but practically, it is not. The frequent check-ups are often overlooked, or for financial reasons, it is difficult to have roentgenograms taken as frequently as necessary. In the meantime, the patient's lesion may become very much more extensive before it is re-examined. I have seen minimal, soft lesions spread and break down into cavities 4 or 5 cm. in size in a few weeks. Those who advocate watchful waiting also fail to take into consideration that many of these patients leave the sanatorium early, and because proper protection has not been given to their lesions, they rapidly become worse under careless living. The fact should also be remembered

that almost all of that large group of patients who present themselves for treatment in the far advanced and hopeless stage have passed, at some time or other, through the stage when their disease was minimal, and could have been controlled by simple measures.

So while it might be possible in some small sanatoria under ideal conditions, to make such frequent examinations with the roentgen ray that very early lesions could be watched safely for a short time without collapse therapy, such instances would be few, and the principle is a dangerous one. The vast majority of patients are cared for in homes and in large public institutions where such careful, frequent examinations cannot be made, and these principles might prove disastrous to many patients who might otherwise be saved.

Many physicians are still waiting for more statistics on the percentage of patients whose disease has become arrested after the use of phrenicectomy or other procedures before instituting them themselves. These additional figures may be of some value, but they are entirely unnecessary. We know now, without any need of further statistics, that a phrenicectomy accomplishes a certain, definite end. It will cause a minimal amount of reduction in lung volume, assist cavities in closing, and add to the necessary rest. If this amount of assistance seems sufficient to cause healing in a given lesion, then it is the procedure indicated, and the lesion must be benefited by it to that extent. If the lesion is more extensive, and requires a greater amount of collapse and rest, artificial pneumothorax is indicated, and again the lesion must be benefited proportionately to the assistance.

It is not to be expected that all patients can overcome the disease regardless of the method used, but the results of these procedures will be almost in direct proportion to the intelligence with which they are applied. In the group of patients with minimal lesions, we may expect recovery, with the proper use of collapse therapy, in almost 100 per cent. With phrenicectomy alone, we reported, as stated above, that we obtained this result in moth-eaten cavities in 90 per cent.

We wish always to assist the patient to become well with the least sacrifice possible, and therefore apply the procedure that seems the least burdensome, and at the same time sufficiently effective. We know that the ceaseless motion of respiration retards and prevents healing, and this must be overcome in varying degrees, according to the extent of the lesion. One should start with the procedure that seems most applicable to the lesion. If this does not, in a very short time, appear to be sufficient, more drastic measures should be added. Cavities must be closed as soon as is possible with safety, and all statistics will vary according to the proper recognition of this rule. If one waits until the disease has advanced beyond the help of a phrenicectomy, the results of this operation in his hands will be negligible. This is, of course, true of all procedures.

It would be better to treat all patients with artificial pneumothorax if it were not for the fact that phrenicectomy is a simpler procedure, and accomplishes the desired result in many patients. If, in any patient, the desired result is not obtained promptly, pneumothorax should immediately be started. If this is done, the patient will have lost no time while the attempt has been made to control his lesion by the simpler measures.

The use of collapse therapy has not been found, except in occasional instances, to be detrimental to the patient either at the time of its use or in after years. In the group of patients with early, minimal disease, with or without cavitation, it is not necessary in some cases to institute a permanent collapse. Crushing of the phrenic nerve causing temporary paralysis of the diaphragm will be sufficient, in some cases, to allow healing. The patient will receive the benefit of the added rest and approximation of the cavity walls for a period varying from a few months to a year, at which time the nerve will regenerate, and the

diaphragm will resume its function. Nothing will have been sacrificed. In 1930, Dr. Wells of Saranac Lake and myself reported simultaneously on a large group of these patients on whom this operation had been performed. We both reported that, in our experience, 90 per cent of these patients had to be re-operated upon when the diaphragm resumed its function, and the nerve removed in order to allow sufficient time for healing or to maintain it. One can somewhat clearly surmise, therefore, what percentage of patients with this amount of disease will become well, and remain so, with bed rest alone.

In those patients with more disease than this, a permanent paralysis of the diaphragm, with or without the use of pneumothorax, is both necessary and desirable, for not only will it be an essential adjunct in the process of healing, but it will remain as a safeguard against reactivation later when the patient resumes his position in society. The slight loss of function following this procedure is rarely noticed by the patient, and the fear of it is entirely unwarranted. If this permanent protection were not given, the future life of the patient would have to be restricted in such a way as to incapacitate him for active life much more seriously than following its use.

This attempt to save unnecessary function proves disastrous in all forms of tuberculous infection. A tuberculous knee must be immobilized permanently with loss of function, as must other joints and the spine if we wish permanent healing. It must be accepted that persons with pulmonary tuberculosis, especially with cavitation, must also maintain some restriction of motion in the diseased part.

Some question the advisability of doing a permanent phrenicectomy because later in life the patient might experience some difficulty from it or might need the same procedure on the opposite side. One might, on the same grounds, question the advisability of removing a tuberculous kidney because it might be found later that the other kidney was diseased. Tuberculous disease must be treated as it is found. In bilateral disease, however, frequent use is made of temporary phrenicectomy until it is ascertained upon which side a permanent phrenicectomy may be most urgent.

Frequent crushings to replace removal have been suggested but, in my opinion, while this is a desirable procedure in some cases, it is not a sound method to be employed when we are dealing with unilateral disease that needs constant and permanent rest. There is always a variable period of time after a crushing in which the diaphragm regains some motion, frequently sufficient to prevent proper rest. This incomplete rest is sometimes enough to allow cavities to reopen, with possible spreads to the other lung before it is detected, and the nerve is again crushed. Because of scar tissue, subsequent crushings become more and more difficult and dangerous. Moreover, any lesion that requires the use of frequent crushings is sufficiently dangerous to warrant an immediate and permanent phrenicectomy to insure permanent healing.

If disease does occur in the contralateral lung later, we may still institute artificial pneumothorax on that side, or if this is impossible because of adhesions, a phrenic crushing may be done. I have performed a considerable number of bilateral phrenicectomies, and have seen no untoward results in any of the patients. However, a phrenic crushing should always be performed in bilateral disease before the nerve is removed in order to determine the effect upon respiration, and because it may be necessary or advisable to do an upper stage thoracoplasty on one or both sides later, and a functioning diaphragm may be desirable.

As a general rule, therefore, it seems to me unsound to refrain from properly caring for a lesion already present because of the possibility of some future happening. The dangers attendant upon this procedure have not, in my hands, been worthy of mention. In over 3,000 patients on whom I have performed this operation, I have

had no operative mortality nor any serious accident. Occasional mishaps such as cutting the wrong nerve, severing the carotid, the jugular, the thoracic duct, etc., have been reported by others, but in experienced hands, these accidents occur very rarely.

There are also, following the use of artificial pneumothorax, occasional and rare accidents such as air embolism, spontaneous collapse of the lung, empyema, and some few unfavorable reactions to novocaine, but these accidents occur so seldom that they cannot be given serious consideration.

Much is said of the danger of diaphragmatic hernia in later years following the use of phrenicectomy. Still, after over twenty years of experience with this procedure both in this country and in Europe, there is only one such case in the literature. I have encountered none. The paralyzed diaphragm, while losing its muscle tone, becomes a very tense, firm membrane, stronger if anything than it was before. I have seen many of these, years after phrenicectomy, and it was difficult to see how hernia could take place.

It seems incongruous to dwell on the possible dangers of these procedures when withholding them will cause such a tremendous toll of lives, and an inexcusable financial burden to the people. Our aim must be to diagnose and treat actively all patients with this disease as soon as possible.

Even in the more advanced and chronic patients, when phrenicectomy and artificial pneumothorax have been ineffectual, excellent results may be obtained from thoracoplasty. This is especially true since the technique of this operation has been improved. The removal of the entire length of the upper ribs to, and occasionally including, the costal cartilages, has entirely changed our conception of the results which may be obtained following this procedure.

Equally as important as treatment, however, is the necessity of proper early diagnosis and case findings, for thousands of people who are in need of treatment are living today in a false sense of security because of reassurance given to them after an inadequate or untrustworthy stethoscopic examination, while many thousands, too, have been sacrificed because of this method of examination. When that time arrives when physicians send their patients to the roentgenologist for assistance in the early detection of the disease instead of depending upon the stethoscope, we shall be on the right approach to the proper treatment of pulmonary tuberculosis. And when those patients who have benefited by this early diagnosis are hospitalized and given the assistance of collapse therapy early in the course of their disease, we shall see the beginning of the end of pulmonary tuberculosis as a serious menace to society.

Vol. XXX, No. 3

THE TUBERCULOSIS PROBLEM IN DETROIT*

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TUBERCULOSIS is classed as a communicable disease and therefore becomes a responsibility of the Department of Health as is the case with acute infectious diseases. The control of tuberculosis by this department, therefore, involves diagnosis, treatment and the segregation of open cases to prevent spread of infection.

The disease is of such long duration that most persons with tuberculosis soon exhaust their savings, their earning power lessens or ceases altogether, and they have to be maintained by public funds. Then again the modern treatment requires hospital and sanatorium facilities, and for this reason a period of institutional care is advisable for all patients. In the sanatorium a patient learns the fundamentals upon which cure depends and the methods necessary to prevent infecting others. These essentials cannot be satisfactorily taught and put into effect in the average home.

Detroit has a unified tuberculosis program, all of which is administered by the Department of Health. This includes diagnostic clinics, case finding in schools, hospitalization of patients, the supervision of indigent patients in their homes, and medical supervision of the tuberculous children in the open air and open window schools.

DIAGNOSTIC CLINICS

A central diagnostic clinic is maintained for indigent persons at the Herman Kiefer Hospital. This is open each week day, and one or more diagnosticians are in attendance. All children are tuberculin tested, and the reactors have a roentgenogram of the chest. Single films are taken as a routine of all adults coming to the clinic and stereoscopic films in special cases.

VALUE OF THE ROENTGENOGRAM

There have been four outstanding discoveries recorded in medical history that have greatly increased our knowledge of tuberculosis. The first of these was the treatise published by Auenbrugger in 1761 in which he demonstrated a method of percussion by which the comparative densities of subjacent parts can be determined. The second was the publication of the book by Laennac in 1819 on "The Diagnostic Value of Mediate Auscultation by Use of a Stethoscope." The third was the discovery of the tubercle bacillus by Koch in 1882, and the fourth was the discovery of the x-ray by Roentgen in 1895. One hundred and thirty-four years elapsed between the first and the last of these important epochal discoveries; and even up to the present time the period since Auenbrugger could be covered by the life span of two individuals.

In relation to world history the knowledge upon which the diagnosis of pulmonary disease rests is a very recent possession. Each of the scientists mentioned thrust forward the then existing knowledge upon which the diagnosis of pulmonary tuberculosis was based. Koch and Roentgen, however, have given us methods of greater precision which have since been elaborated in the clinic and x-ray laboratory until the diagnosis of pulmonary tuberculosis may be made with greater accuracy than is possible by physical examination.

For the diagnosis of pulmonary tuberculosis we place but little dependence on auscultation and percussion in our clinics. It is a conservative statement to say that 20 per cent of error will be made by physicians, even those specializing in tuberculosis, who depend upon a physical examination to diagnose pulmonary tuberculosis. At least 60 per cent of minimal cases and

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27–30, 1932.

some of the advanced cases, especially those with bilateral fibroid disease, will be missed. Not only will cases of pulmonary tuberculosis be missed, but many others will be erroneously diagnosed as having that disease. This leads to serious consequences. The undiscovered cases lose valuable time in securing proper treatment and the non-tuberculous cases are caused much unnecessary inconvenience, expense and worry. Furthermore, the really incipient form of tuberculosis, the childhood type, cannot be diagnosed by physical examination even by the most skilled physicians. Only by the roentgen examination can it be demonstrated. The relative value of the two methods as showing the extent of disease is illustrated in the following tables.

Note the change in classification of those before 1929 and after that date. In 1927 and 1928 the diagnosis and classification were made largely by physical examination. About the middle of 1929 a change in procedure was made, and all patients thereafter were classified according to the roentgen findings. The shift from minimal to the tients examined in 1932 was 14,217; 20.3 per cent of these persons were found to have some form of tuberculosis.

About one-third of the new patients were referred by physicians for diagnosis, largely because the patient could not afford to pay a roentgenologist's fee. In these cases a report is sent to the physicians giving the diagnosis as shown by the roentgenogram and sputum examination. A physical examination is made, but more for the purpose of finding other pathological conditions than for its value in demonstrating tuberculosis. Another third of the patients came in for examination because of illness or symptoms which led them to suspect tuberculosis, and the balance were persons who came to the clinic for a check-up because of exposure. The field nurses try to get all contact children into the clinic for examination. Eighty-five per cent of the children living in a home in which a case of tuberculosis was found were given a tuberculin test and roentgen examination. Of these, 18.5 per cent were found tuberculous; 1,927 other children without history of exposure were examined, and but 10.5 per cent were diagnosed as tuberculous.

CLASSIFICATION OF DIAGNOSED CASES

Year	Minimal per cent	Moderately Advanced per cent	Advanced per cent	Total No.
		Classified by Physical Examination		
1927	36.2	52.5	11.2	1711
1928	41.0	46.8	12.1	1932
1929	32.0	51.7	16.3	2323
		Classified by Roentgenogram		
1930	15.2	29.3	55.2	1927
1931	20.8	30.3	48.9	1951
1932	17.8	34.4	47.8	1627

far advanced group is very striking as a study of the table will show. The reason for this is that the roentgenogram reveals a greater area of disease and the presence of cavities that cannot be demonstrated by physical examination.

CLINIC ATTENDANCE

This has increased from 21,000 in 1928 to 44,000 in 1932. The number of new pa-

FIELD NURSING

The city is divided into nursing districts. There are five in which generalized nursing is done and eighteen others in which there is specialized nursing, the nurse giving her whole attention to the tuberculosis cases in her area. Each nurse is expected to follow up the cases diagnosed in the clinic, the patients discharged from sanatoria and all reported cases of tuberculosis who are

not under the direct supervision of a private physician. She gives instruction as to proper sleeping quarters, the value of fresh air, teaches concurrent disinfection and care of sputum, personal hygiene, proper diet, instructs the patient how to control cough and to cover the mouth when coughing, encourages the patient to continue treatment until results are obtained. She endeavors to get all contacts, adult and children, into the clinic for examination. In cases under the care of a private physician similar instructions are given with the physician's consent.

CASE FINDING AMONG SCHOOL CHILDREN

In many places in the United States school children are being tuberculin tested and the reactors roentgenographed to find the cases of tuberculosis before symptoms develop. The tuberculin test is used as a screen to determine infection, and a roentgen examination of these positive reactors will reveal the children who have developed pulmonary and tracheobronchial lymph node tuberculosis.

The Tuberculosis and Health Society of Wayne County cooperates with the Department of Health in holding clinics in the schools. During 1929, 1930 and 1931, 16,042 school children were tuberculin tested. These represented 67 per cent of the enrollment in these schools. Thirty-two per cent of the high school pupils and 19 per cent of the grade pupils showed a positive tuberculin reaction. There were 3,499 roentgenograms taken of the reactors. In the high schools 0.4 per cent of the students and three in 11,216 grade school pupils were found to have the adult type of tuberculosis. This is usually a fatal form of disease in children unless detected early and adequate and prompt treatment given. These cases are often spreaders of tuberculosis, and they should be excluded promptly from school. For this reason alone the finding of even one justifies the effort and expense of such surveys. In addition, however, there was 4.6 per cent with the childhood type of tuberculosis in the high schools and 3.5 per cent in the grade schools. These children will usually overcome their disease if their condition is known and they are given proper care and supervision. It is very important that they be separated from the source of infection. Frequently the finding of a tuberculous child in the school will, if followed up, lead to the diagnosis of tuberculosis in other members of the family.

OPEN AIR SCHOOLS AND OPEN WINDOW ROOMS

In the public school system there are twelve open air schools and fifty-two open window rooms in school buildings. There are also open air schools at the Maybury Sanatorium and at the Detroit Tuberculosis Sanatorium. In the public school system 3,809 pupils were enrolled in these special schools last year. The children are assigned through the tuberculosis clinic, and the basis of selection is a positive tuberculin test with roentgen evidence of childhood type tuberculosis or a positive tuberculin test associated with malnutrition or poor general condition. These children are under the supervision of one of the clinic physicians throughout the school year, and roentgenograms are taken every six months.

HOSPITAL AND SANATORIUM CARE

The city owns two large institutions with a capacity of 1,500 beds used exclusively for the treatment of tuberculosis patients. These are operated by the Department of Health. The Herman Kiefer Hospital with 670 beds is used as a receiving hospital for all forms of tuberculosis. The William H. Maybury Sanatorium with 830 beds is situated at Northville, twenty-five miles from Detroit. After a period of observation at the Hospital the most favorable cases are transferred to the Sanatorium. Patients who cannot be accommodated in these two institutions are assigned to seventeen other hospitals and sanatoria. Three of them are general hospitals which only recently, because of the large number of vacant beds, have been willing to accept tuberculosis cases. Because of these added facilities

2,236 tuberculosis patients are being given hospital care. This represents about one-third of the registered tuberculosis cases in the city.

There is no waiting list, and patients can be hospitalized promptly as applications are made. This gratifying situation was not possible until there were two available beds for each death. This appears to be the proper ratio necessary to care for all cases of tuberculosis where adequate clinic diagnostic service is maintained.

Wayne County pays the maintenance costs of all the indigent patients hospitalized in these city and private institutions. The County is reimbursed one dollar per day per patient by a subsidy from the State.

TUBERCULOSIS IN THE NEGRO

There are about 120,000 negroes in Detroit, comprising 8 per cent of the city's population. They contribute 32 per cent of the total deaths from tuberculosis. The rate per 100,000 for 1932 for the whites was 50.3, for the colored 312.

Efforts have been successful in arousing the interest of the colored physicians in this serious problem of their race, and they have become active in diagnosis and treatment. Four small hospitals with a total capacity of 200 beds are now operated and staffed by colored physicians and nurses.

REGISTERED CASES OF TUBERCULOSIS

There are now 7,383 cases of tuberculosis on the register. In 1932 there were 1,052 deaths. Therefore, we have approximately seven known cases of tuberculosis for each death. Thirty per cent of the known cases are in hospitals and 70 per cent are living at home, many of whom have had a period of sanatorium treatment. But 269, or 3.6 per cent, are under the care of private physicians. The others are under clinic supervision.

The financial status of all patients hospitalized is investigated by the County Auditor's office. They report that less than 10 per cent are able to pay even a small part of their hospital maintenance. This shows to what a large extent tuberculosis has become a public health problem and why so few patients are financially able to employ a private physician.

TREATMENT

The treatment of pulmonary tuberculosis has been revolutionized in the past few years and to carry it out requires that the sanatorium be equipped with an operating room or have an affiliation with a general hospital. The medical staff should include a thoracic surgeon and consultants representing the various specialties. Tuberculosis is a disease of long duration, and during its course a patient may develop any one of the other ills that affect mankind. A good roentgenological department is indispensable. After the diagnosis is made frequent roentgenograms are essential in recording changes occurring in the course of the disease. The roentgenogram records the location and extent of the lesion and gives information as to the character of the infiltrations or consolidations, the size and location of cavities, the presence of fluid, displacement of trachea and mediastinum, and size, outline and location of the heart—all factors that are necessary to know before deciding upon the form of treatment best suited to the patient.

Artificial pneumothorax treatments could not be carried out without the use of the roentgenoscope to observe the amount of collapse and the effect on the diseased area. At the Herman Kiefer Hospital and Maybury Sanatorium over 2,000 pneumothorax treatments are given each month, and a roentgenoscopic examination is made of each patient before and after each treatment.

The therapeutic use of the roentgen ray in sanatoria is practically limited to the treatment of tuberculous cervical lymph nodes. In such cases it is found of great value.

RESULTS OF TREATMENT

The results of treatment at the Herman Kiefer Hospital and William H. Maybury

Sanatorium should be considered together, as otherwise they would be misleading. The policy adopted in 1929 to use the Herman Kiefer Hospital as a receiving hospital and transfer the favorable cases to the Maybury Sanatorium has been continued. The cases at the Sanatorium needing bronchoscopic examination, a thoracoplasty or major surgery of any kind are transferred to the Herman Kiefer Hospital for operation. Therefore, many cases begin treatment at one institution and finish in the other. For that reason few patients are discharged from the Herman Kiefer Hospital with the disease arrested or quiescent, the favorable cases having been sent to Maybury Sanatorium to finish the cure.

Last year, of the patients admitted to Herman Kiefer Hospital, 800 were favorable for treatment and 453 were so far advanced at the time of admission that treatment offered little hope for recovery. It is this unfavorable group that accounts for the large number of deaths at the Herman Kiefer Hospital. It is more difficult to persuade a patient in the minimal stage without notable symptoms to accept sanatorium treatment than one who is really ill. Education of doctors and the laity that early active treatment is as essential to cure as is early diagnosis will bring about an improvement in this condition.

The following table shows some encouraging results from the efforts made to get patients under treatment early. There is a decided shift in percentage of far advanced cases toward the moderately advanced and minimal stage groups.

CLASSIFICATION OF PATIENTS ADMITTED TO HERMAN KIEFER HOSPITAL

Year	Minimal Per cent	Moderately Advanced Per cent	Far Advanced Per cent	Deaths Per cent
1929	10.1	14.4	75.5	35.0
1930	10.0	14.5	75.5	31.2
1931	13.3	25.1	61.6	21.6
1932	15.4	28.6	56.0	20.3

Collapse therapy is being used to a greater extent each year, with correspondingly greater improvement in the patients under treatment. The decrease in deaths in four years at the Herman Kiefer Hospital from 35 per cent to 20.3 per cent and at the Maybury Sanatorium from 18 per cent to 6.5 per cent is further proof that the treatment given is much more effective.

The following table will indicate the improvement in the results of treatment that has taken place at the Maybury Sanato-

COMPARISON OF PERCENTAGES OF RESULTS DURING PAST SIX YEARS OF DISCHARGED ADULTS

	1927 Per cent	1928 Per cent	1929 Per cent	1930 Per cent	1931 Per cent	1932 Per cent
Apparently arrested	8.1	14.0	18.5	27.4	34.1	35.4
Quiescent	17.8	7.2	9.8	21.8	19.4	16.8
Improved	19.5	21.2	17.1	17.7	15.4	17.6
Total Favorable Results	45.4	42.4	45.4	66.9	68.9	69.8
Unimproved	21.2	23.6	22.4	14.4	13.3	18.6
Stay too short to note change	7.6	4.4	9.5	8.4	6.3	4.8
Died	25.8	25.2	18.1	10.0	10.0	6.5
Non-tuberculous	0.0	4.4	4.6	0.3	1.4	0.2

rium in the last six years. In 1927 only 8.1 per cent of the patients were discharged as apparently arrested whereas in 1932 it had risen to 35.4, and the total favorable results had increased from 45.4 per cent in 1927 to 69.8 per cent in 1932.

A recent survey of the patients under supervision of the Detroit Department of Health showed that of the 2,218 adults with pulmonary tuberculosis receiving hospital or sanatorium care 75.7 per cent had had pneumothorax, phrenic nerve surgery or thoracoplasty, or a combination of these methods of treatment as shown in the following table.

COLLAPSE THERAPY PROCEDURES THAT HAVE BEEN EMPLOYED IN THE TREATMENT OF PATIENTS WITH PULMONARY TUBERCULOSIS IN THE INSTITUTIONS AS OF JANUARY, 1933

Procedure Employed	Minimal	Moderately Advanced	Far Advanced	Total
Pneumothorax unilateral, alone	13	156	342	511–23.0%
Pneumothorax bilateral, alone	0	11	100	111– 5.0%
Pneumothorax and phrenicectomy, same side	8	87	194	289–13.0%
Pneumothorax and phrenic surgery on opposite sides	0	15	61	76– 3.4%
Pneumothorax bilateral with phrenic surgery	0	0	12	12– 0.6%
Pneumothorax with phrenicectomy and intrapleural pneumolysis	0	0	1	11– 0.04%
Pneumothorax and intrapleural pneumolysis	0	8	6	14– 0.6%
Phrenicotomy (crushing of phrenic nerve) alone	11	16	18	45– 2.0%
Phrenicectomy (evulsion or complete dissection of nerve) alone	81	204	182	467–21.1%
Bilateral phrenic nerve surgery	0	1	9	10– 0.4%
Bilateral phrenicectomy with unilateral pneumothorax	0	0	1	1– 0.04%
Thoracoplasty	0	8	123	131– 6.0%
Extrapleural pneumolysis (paraffin filling, muscle transplants, etc.)	1	0	4	5– 0.2%
Other surgery on chest—scalenotomy, first rib removal, etc.	0	0	6	6– 0.27%
Number receiving no form of collapse therapy	92	118	329	539–24.3 %
Total, without duplicates	206	624	1388	2218

1,679 collapse therapy cases out of 2,218 adults, or 75.7 per cent.

REDUCTION OF DEATH RATE

There was but little change in the death rate from tuberculosis in Detroit during the ten years preceding 1929. Since then the number of deaths has shown a steady decrease each year. For 1928 the rate for all forms of tuberculosis was 95.1. In 1929 it was 93.9, in 1930, 82.7, in 1931, 73.8, and in 1932, 70.3, a drop of 26 per cent in the last five years.

TUBERCULOUS MENINGITIS

There was also a significant decrease in deaths from tuberculous meningitis as compared with the preceding years. From an average number of 122 deaths per year for 1928, 1929 and 1930 the number dropped to 72 in 1931 and 74 in 1932, or a decrease of 40 per cent. As there has been found no specific treatment for this disease, and only a rare case is known to recover, we must assign the reason for this lessening incidence of tuberculous meningitis to fewer opportunities for children to become infected through exposure to open cases of pulmonary tuberculosis in the home.

Many factors have contributed to bring about the substantial decline in the tuberculosis rate. Among them are adequate hos-

pitalization facilities, which has brought about segregation of many spreaders of infection and gives opportunity for more effective treatment. Early diagnosis is made possible by the general use of the roentgenogram. The method of tuberculin testing contacts and school children and a roentgen examination of the reactors finds cases of tuberculosis before symptoms appear and when the patient is in a condition to respond favorably to treatment. Finally, the use of the pneumothorax or of some form of thoracic surgery in all cases where collapse therapy is applicable to supplement the bed rest which all patients receive. All these procedures have a part in carrying on a successful campaign against the tubercle bacillus.

CALCIFICATION IN AORTIC AND MITRAL VALVES

WITH A REPORT OF TWENTY-THREE CASES DEMONSTRATED IN VIVO BY THE ROENTGEN RAY*

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INTRODUCTION

CALCIFICATION in chronically diseased valves of the heart is a frequent finding at the post-mortem table. For many years the pathologist and the cardiologist have been asking the roentgenologist why he could not show these calcified areas by roentgen examination of the living patient. Our defense has been that the equipment has not been powerful enough or fast enough to do so. It is a sad commentary on the ability of the thousands of men, who do roentgenoscopy almost daily, to learn that we have had the proper equipment for years, certainly for thirty of the thirty-eight years since Roentgen's discovery. As is so often the case, one sees only what one looks for, and if anyone had thought to actually look for these calcified valves in a series of cardiac patients, he certainly would have seen them, as they are easily visible with the ordinary roentgenoscope and are a very common finding in patients with chronic valvular heart disease. The recording of these shadows on films is a different matter, and it is only recently that we have had the equipment powerful enough and fast enough to make the short exposures necessary to delineate them.

Our first case of calcified heart valve visible by roentgenoscopy in vivo was recorded ten years ago,[8] but in a rather uncertain manner, as it could not be demonstrated on films at that time. Only occasionally since then had a similar finding been recorded until Christian[4] began his studies on "Aortic Stenosis with Calcification." From a study of post-mortem cases he was able to develop criteria whereby he could state that aortic stenosis with a considerable degree of calcification was present in a given case. He sent such cases to us with the specific request to demonstrate the calcification, if possible, and we were able to do so in nearly all of the cases. One of his early cases was published,[5] it being the first case of aortic stenosis with calcification recognized in vivo to appear in the literature. Having developed a satisfactory method of roentgenoscopic and roentgenographic examination, we independently found other cases of calcified aortic valves and an equal number of calcified mitral valves. We are reporting here our first 25 cases of calcified valves, 23 of which were demonstrated by roentgen examination in the living subject, and in the other 2 after death. One of these 2 was missed at roentgenoscopy although the diagnosis was made clinically, and the other patient was not examined by us until after death, the films confirming the clinical diagnosis. In 4 of the patients who have come to autopsy, 3 had calcified aortic valves and one had calcification in the mitral valve.

HISTORICAL

The first recorded case of intracardiac calcification, demonstrated by roentgen examination ante mortem, was published in 1903 by Rudis-Jicinsky.[19] The illustration accompanying his article is so poor and the technical difficulties of those times were so great, that it is hard to believe he actually demonstrated calcification in the heart valves. The report itself is vague and unsatisfactory, and it is not stated that diagnosis was made ante mortem. This probably

* From the Department of Roentgenology and the Medical Clinic of the Peter Bent Brigham Hospital, Boston, Mass. Read in abstract at the 20th Reunion of the Hospital Staff, May 4–6, 1932.

represents a case of ex post facto diagnosis.

In 1908 Simmonds[21] published a fundamental work on intracardiac calcification as shown by roentgen examination of hearts removed at autopsy. He divided the lesions by their location into four main groups: pericardial, endocardial, myocardial and arterial (coronary). No record was made of attempts to demonstrate these areas in the living subject.

Pericardial calcification was the first entity to be reported as demonstrated in vivo, and in 1922 Klason[13] summed these up, added 4 cases of his own and reported one case of intracardiac calcification, probably the first authentic case of calcified valves demonstrated in a living patient. He found ring-shaped shadows of calcification in the region between the auricle and ventricle, noted their movement from right to left with systole and concluded that they were located in the annulus fibrosus of the mitral valve.

In 1924 one of us with Cutler[8] reported 5 cases of calcification in the heart. In 4 of these the calcification was chiefly pericardial, but one of them (Case 1) at autopsy showed marked calcification in the aortic, mitral and tricuspid valves. These were not recognized ante mortem. However, Case v, reported briefly and not confirmed by autopsy, was recognized as showing calcification in the mitral valve. This patient cannot now be traced, and the final proof is lacking.

In 1925 Fleischner[10] reported a case of calcification in the annulus fibrosus with the ante-mortem diagnosis confirmed at autopsy. Post-mortem films also revealed calcification in the coronary arteries and in the ductus arteriosus.

In 1932 Saul[20] published a short but excellent report of 3 cases of intracardiac calcification, with observations and conclusions quite similar to ours independently being made at the same time. He described the roentgenoscopic findings in detail and concluded, as we have done, that this is the best method for demonstrating the calcified valves. All three of his patients had calcification in the mitral annulus fibrosus; one of them was confirmed by autopsy. Saul was unaware of the American literature on this subject.

Shortly after Saul's report, Parade and Kuhlmann[18] published 4 cases of intracardiac calcification, 3 in the mitral valve and one in the aortic valve.

TABLE I

AORTIC VALVE CALCIFICATION

Number	1	2	3	4	5	6	7	8	9	10	11	12
Age	53	56	56	59	60	63	68	69	70	70	72	72
Sex	m	m	m	m	f	m	f	m	m	f	m	m
History of rheumatic fever	+	±	+	±	o	o	o	+	o	+	o	o
Years between rheumatism and discovery of calcification	51	50 (?)	42	50 (?)	o	o	o	60	o	23	o	o
Signs of cardiac insufficiency	+++	++++	+	++	o	o	±	o	+	o	±	o
Duration of cardiac symptoms in years	5	4	2/12	6 6/12	o	3–4	2	o	5	o	2	2/12
Duration of known heart disease in years	1/12	12/12	34	o	o	6/12	o	11	5	23	o	o
Basal thrill	+	o	+	+	+	+	o	+	+	+	+	+
Basal systolic murmur	+	o	+	+	+	+	+	+	+	+	+	+
Basal diastolic murmur	+	o	+	o	o	o	o	+	o	o	o	o
Decreased pulse pressure	o	+	o	+	o	+	o	o	o	o	o	o
Cardiac hypertrophy	+	+	+	+	+	+	o	+	+	+	+	+
Roentgen demonstration of calcification	+	+	o	+	+	+	+	+	+	+	+	+
Blood pressure	120/65	155/120	180/95	112/100	200/110	160/110	110/68	180/80	140/54	190/90	180/96	115/50
Signs of mitral disease	o	(?)	+	o	o	o	o	o	o	o	o	o
Auricular fibrillation	o	+	+	o	o	o	o	o	o	o	o	o

Cases of aortic stenosis with calcification, arranged in the order of the patients' ages.

CLINICAL

A. Aortic Stenosis with Calcification.

In summing up our 12 cases of aortic stenosis with calcification (Table 1) it was noted that the clinical characteristics agreed closely with the criteria postulated by Christian.[4] These were as follows:

1. *Occurrence chiefly in males relatively late in life.* There was a preponderance of males in our series, 9 males to 3 females. The average age of the group was sixty-four years. The average age for the males was sixty-one and for the females sixty-six. The youngest patient in the series was fifty-three years old and the oldest seventy-two at the time of the discovery of the calcification.*

2. *History of rheumatism early in life.* Six of our 12 cases gave a definite rheumatic history. Four of these showed a lapse of fifty years or more from that infection to the discovery of the calcified valves. In Case x, the etiology of the heart lesion was considered to be a severe infectious arthritis that occurred twenty-three years previously. Attempts were made to verify this and to determine the time of onset of the cardiac lesion through the records of earlier hospitalizations. These were unavailing. There were many reasons why a history of a preceding rheumatic fever was obtained in only one-half of the patients. This process, if it had occurred, had done so at an early age, and the details of the infection could not be remembered. One patient was unconscious; others suffered from senile changes. The history of childhood diseases was rather poor for the entire group. Then, too, we considered only rheumatic fever, chorea and severe "growing pains" as constituting a positive history.

3. *Slow progression of the lesion with symptoms of decompensation appearing late though not necessarily prolonged after development.* The majority of our group were hospital patients, and 7 of these showed some evidence of cardiac failure by the usual signs. Cardiac symptoms were present in 9 cases, and these had been present from two months to five years. Only 4 of the patients were unaware of their heart damage and in 8 cases the duration of that knowledge varied from one month to thirteen years.

4. *Presence of a systolic thrill and harsh, loud systolic murmur in the aortic area, with or without a diastolic murmur of aortic insufficiency.* In 10 of our 12 cases there was a definite basal thrill and in 11 cases a roughened, harsh basal murmur. Both were systolic in time. A diastolic murmur was heard at the base in only 3 cases, though the presence of aortic insufficiency could be suspected from the low diastolic pressures in 3 additional cases.

5. *Often a characteristic pulse with normal or decreased pulse pressure.* The pulses of our patients were often slow and small in amplitude. A decreased pulse pressure was noted in 3 patients, 2 of whom showed fairly marked myocardial insufficiency.

6. *Enlargement of the heart.* Cardiac hypertrophy was present in 11 of the patients. This was determined clinically and checked by the roentgen examination.

7. *Roentgenographic demonstration of calcification in the region of the aortic valve.* Eleven patients were shown to have intracardiac calcification in the aortic valve area by the roentgen ray. The remaining case is included to show that very small amounts of calcium deposit may be overlooked during life.

8. *Typical autopsy findings in the aortic valve, other valves not organically abnormal, with great hypertrophy of the heart.* Our autopsy material is mentioned later.

9. *Miscellaneous findings.* The blood pressures tended to be elevated in 7 patients as evidenced by the diastolic readings. Case 11 showed questionable signs of mitral stenosis and the diagnosis of mitral disease had been made on previous hospital admissions. The calcification present was

* A twenty-eight year old male was recently examined anatomically and reported.[3] He had marked calcification of the aortic valve with no change in the mitral valve and no history of rheumatism. The lesion was typically that which occurs in older individuals. One year before his death he was roentgenoscoped in the Peter Bent Brigham Hospital, Roentgen Ray Department, and no intracardiac calcification was found. This was done by a House Officer who evidently did not look for calcified valves.

in the aortic area roentgenographically, and unfortunately, though the patient died, autopsy permission was denied so that this could not be checked. Mitral disease was considered to be present in Case III, and slight stenosis and insufficiency were demonstrated pathologically. In only these two patients was there any evidence of organic disease of the mitral valve, and in these two the mitral lesion seemed but slightly developed. Cases II and III were the only ones showing auricular fibrillation. The Wassermann and Hinton reactions on the blood serum were negative in all of the cases. Ten years previously Case XII was diagnosed general paresis, but this had been completely arrested. Electrocardiograms did not show characteristic curves for the group.

1. *Age and sex incidence.* There were 8 males and 5 females. Their average ages were 49.5 and 52.6 years respectively. The youngest patient was twenty-four years of age and the oldest seventy-seven years.

2. *History of rheumatic fever.* A definite history of rheumatic fever was obtained in 7 of the cases and all of these were in the youngest 9. Three had had rheumatic fever more than once.

3. *Time relationships—failure.* Whenever present in the history, the rheumatic fever had occurred from eleven to thirty-six years previous to the discovery of the calcification. This was a shorter interval than was noted in the aortic group but was to be expected, remembering the average ages for the groups. Twelve cases had had cardiac symptoms from nine months to nine years. Twelve cases had been aware of the existence of their heart disease, and had known of it from one month to sixteen years. The youngest patient (aged twenty-four) could give no history of rheumatic fever, and, though she had been told of her heart lesion, she did not have any cardiac

TABLE II

MITRAL VALVE CALCIFICATION

Number	13	14	15	16	17	18	19	20	21	22	23	24	25
Age	24	33	34	38	38	42	44	52	56	58	72	76	77
Sex	f	m	m	f	m	m	m	f	m	m	f	m	f
History of rheumatic fever	o	+	+	+	+	+	+	o	+	o	o	±	±
Number of attacks of rheumatic fever	o	2	1	3	1	2	1	o	1	o	o	—	—
Years between rheumatism and discovery of calcification	o	23	16	30	11	25	22	o	36	o	o	60–70 (?)	50–70 (?)
Signs of cardiac insufficiency	o	o	+	o	++	+++	+	+	o	+++	o	o	+
Duration of cardiac symptoms in years	o	4	9	1	2	3	5 9/12	5	4	9/12	7	2	30
Duration of known heart disease in years	10	4	16	1	11	3	5 9/12	5	3	1/12	o	2	30
Apical thrill	o	+	+	o	o	o	+	o	o	o	o	o	o
Apical diastolic murmur	+	+	+	+	+	+	+	+	+	o	o	o	o
Apical systolic murmur	+	+	+	+	+	+	+	+	+	o	+	+	+
Blood pressure	118/50	115/75	116/44	130/90	130/75	145/100	118/70	118/78	165/80	105/60	190/74	148/70	148/70
Cardiac hypertrophy	+	+	+	+	+	+	+	+	+	+	+	o	+
Roentgen demonstration of calcification	+	+	+	+	+	+	+	+	+	+	+	+	+
Signs of aortic disease	+	+	+	o	o	o	o	o	o	o	o	o	o
Auricular fibrillation in years if known	o	+	9	o	+	+	5 9/12	4	+	+	o	o	o

Cases of mitral disease with calcification, arranged in the order of the patients' ages.

B. Mitral Disease with Calcification.

There were 13 cases of calcification in the mitral valve. These are tabulated in Table II. An effort was made to establish a clinical picture that might enable us to diagnose during life the presence of calcification in mitral disease by means other than the roentgen ray, but this failed.

symptoms. In the 4 older patients, one was entirely unaware of any heart disease though she was seventy-two years old and had had cardiac symptoms for seven years. The other 3 patients had had cardiac symptoms for two, seven, and thirty years. The usual signs of cardiac insufficiency were noted in 7 of the 13 patients.

4. *Murmurs and thrills.* An apical thrill was found in only 3 of the 9 younger cases, but in view of the fact that 7 of the patients' hearts were fibrillating this was to be expected. A diastolic and systolic murmur were heard at the apex in all 9 youngest patients. The 4 older patients did not show either apical thrills or diastolic murmurs. A systolic murmur was present in 3 of these 4 cases. This was not surprising at the ages of seventy-two, seventy-six and seventy-seven with slight increases in blood pressure, and chronic myocarditis.

5. *Blood pressure.* The blood pressures for the entire group tended to be low, increasing slightly in the oldest patients.

6. *Enlargement of the heart.* Cardiac hypertrophy was present in 12 of the 13 cases.

7. *Roentgenographic demonstration of calcification.* Calcification in the mitral valve area was seen in all of the cases.

8. *Miscellaneous findings.* Auricular fibrillation appeared in 8 of the 13 cases. It is interesting to note that the clinical signs of aortic valvular disease appeared only in the 3 youngest patients in this group (Cases XIII, XIV and XV). The Wassermann and Hinton reactions on the blood serum were negative in all of the cases. Electrocardiograms yielded no information that could be applied to the problem of calcification of the valves.

The seemingly artificial division of the mitral cases into two groups, a younger (9 cases) and an older (4 cases) group, is well borne out by a study of the 11 cases reported in the literature[8,10,13,18,20]. The reported cases of the younger group showed definite signs of mitral stenosis whereas the older patients entered hospitals or dispensaries showing at most a systolic murmur at the apex. Fleischner's case, aged eighty-five, Saul's case, aged eighty, and Parade and Kuhlmann's case, aged seventy-two, all showed calcification in the mitral ring on pathological examination. These patients did not show evidence of mitral stenosis or insufficiency on clinical examination.

Though we cannot offer absolute proof because of the paucity of our post-mortem material, we do feel that the younger patients who presented definite clinical evidence of mitral valve disease showed smaller amounts of calcium deposit which we think is mainly in the valve leaflets. In the older group of patients, who presented no evidence of mitral disease clinically, we feel that the heavy, ring-shaped shadows that have been described were more apt to be in the annulus fibrosus.

From the clinical findings, then, it is not possible with our present knowledge to diagnose calcification in a case of mitral stenosis. It may be suspected, however, because of its frequent occurrence. In older patients calcium deposit may be present but unsuspected. They often do not have physical signs of cardiac disease. In these cases the calcification is apt to be in the annulus fibrosus.

The question of the importance of the finding of calcification in heart valves is an interesting one. In all of these cases one may infer that the process has been present for a long time when the calcification is found, and that the causative process has long since passed. The roentgen demonstration of calcification in the aortic valve is a valuable adjunct in the diagnosis of aortic stenosis with calcification. We believe that it will be of definite help in establishing a diagnosis of chronic valvular heart disease, confirmatory usually, but in certain cases of critical value. We believe that rheumatic fever is the preceding and causative agent in many of the cases. Syphilis has not caused such calcified lesions in any of our cases. In our group of patients with calcification of the valves, subacute bacterial endocarditis has so far been absent as a complication.

ETIOLOGY AND PATHOLOGY

Calcium salts have been found deposited in all of the various structures of the heart. Saul[20] has summed these up as follows: (1) pericardial calcification, the highest degree of which is called "armoured heart" (Panzerherz); (2) coronary sclerosis; (3) calcification of the myocardium; (4) calcification in the annulus fibrosus; (5) calcification in the endocardium; (6) calcification in cardiac aneurysm; (7) calcification of cardiac thrombosis; (8) tumors of the heart and pericardium may show calcification, but these are extremely rare. These various forms are differentiated easily enough pathologically, and most of them are roentgenologically demonstrable. The cause of these various deposits is difficult to determine.

Calcification occurs in *normal* tissues in two locations: bone, and the rare condition of "calcium metastasis."[24] In all other locations it is deposited in *abnormal* tissue. For the myocardium Diamond[9] finds in a recent review of the literature that calcification occurs secondarily to degeneration or necrosis of muscle fibers due to vascular, inflammatory or toxic conditions. The important point is that for tissues in general, degeneration of some sort precedes calcium deposition. The process concerned with this precipitation of calcium is still unknown though many theories of the mechanism have been advanced. Wells[24] favors a physicochemical view.

Though no attempt was made to cover the entire literature on the subject of calcification in heart valves, a few opinions may be briefly quoted. These are naturally divided into: (I) those subscribing to Mönckeberg's sclerosis theory; (II) those believing rheumatic fever to be the etiological agent; and (III) those considering the etiological proof indefinite for either of these groups.

I. Mönckeberg,[17] in considering calcification in the aortic valve, concluded that the process was not the result of an inflammatory lesion. He believed that the calcium was deposited in the fibrous tissue of the valves continuous with the wall of the aorta, and that the cause was a degeneration of the media of the aortic wall. Clark[6] studied 87 cases of calcareous aortic valvular disease. He excluded 8 cases because of a definite history of rheumatic fever and thought the rest to be upon a degenerative arteriosclerotic basis. Tuohy and Eckman,[23] while admitting that the determinative factors of calcified aortic valves were speculative, accepted Mönckeberg's theory. Martens[15] has recently discussed the relationship between calcification of the annulus fibrosus of the mitral valve, senile endostosis and calcification of the intervertebral discs. These he found to be frequently associated and he believed that inflammation was the cause in some cases. He, however, considered all of these changes to be regressive in character. Geerling[11] studied eight hearts post mortem and came to the conclusion that Mönckeberg's ascending sclerosis of the aortic valves was identical with the calcification of the annulus fibrosus of the mitral valves. He considered the process to be due to a compression of the small arteries of the region because of the contractions of the heart muscle resulting in insufficient blood supply, increased connective tissue and finally calcification.

II. Cabot[2] studied 28 cases of pure aortic stenosis and found that the history of rheumatic fever was as frequent as it was for the cases of rheumatic mitral disease. He would not believe that an arteriosclerotic process would limit itself to one valve and concluded that the lesion was due to rheumatic fever. Christian's[4] report showed that 11 of his 21 patients with aortic stenosis and calcification had a definite history of rheumatic fever. This led him to the conclusion that the causative factor was in all probability rheumatic fever. Boyd[1] also believed the unproved relationship to be sound.

III. Clawson, Bell and Hartzell[7] in a study of 15 cases of aortic calcareous nodules could find no evidence in favor of an inflammatory origin. They did find that

the root of the aorta was particularly free from arteriosclerotic change. Thus they considered the etiology as unknown but separate from a rheumatic process. Margolis, Ziellessen and Barnes[14] studied 42 cases of calcareous endocarditis of the aortic valve. Some of their cases seemed to be the result of an inflammatory injury while others seemed to represent the result of a non-inflammatory degenerative process. They concluded that the etiology could not be determined with certainty. Grant, in a recent lecture delivered before the New England Heart Association, stated that the etiology of calcification in the aortic valves is indeterminable. Kaufmann[12] believed that calcification of the annulus fibrosus occurred quite independently from rheumatic fever, but that the calcium deposited never reached the large amounts found to follow an inactive endocarditis. Thalhimer,[22] after observing that bacteria never could be found in any of the chronic lesions of valves, believed that the damage was non-bacterial, and he proposed an ingenious theory concerning their development. Infections (scarlet fever, measles, tonsillitis, pneumonia, etc.) resulted in a slight fibrosis of the valves, insufficient to cause signs or symptoms, but enough to reduce the proper resiliency and elasticity of the normal valves. Repeated insults of this nature led to thickening. Any strain upon these valves produced minute thromboses and the resultant fibrosis added to the thickening. These processes could occur again and again, eventually leading to cardiac symptoms and signs. Proof for this mechanism, however, is lacking.

As mentioned above in our cases we were able to get a history of rheumatic fever in 7, possibly 9 of 13 cases of mitral disease. In the aortic group we obtained a history of rheumatic fever in 6 of the 12 cases. Of those that were studied anatomically, 3 had a history of rheumatic fever and one was unconscious making a satisfactory history unobtainable.

As seen at autopsy, the calcium deposit in the aortic valves varied tremendously in amount. In Case III the aortic valve cusps were thickened. At the junction of the right and left posterior aortic cusps there was a warty calcified mass, 8 mm. in diameter. This small amount of calcium deposit was not visualized by the roentgen ray ante mortem. The mitral valve showed slight insufficiency and stenosis but no calcified areas. The evidence for a rheumatic etiology was considered to be clear cut. In Case VIII the aortic leaflets were converted almost entirely into hard calcified masses. This calcification stopped rather abruptly at the attachment of the cusps to the aortic wall, but a few calcified patches were seen in the sinuses of Valsalva. Above these there was a thin ring of small calcium plaques. The anterior leaflet of the mitral valve showed many small, irregular, yellowish-gray thickenings that were calcified. Slight mitral insufficiency was present but no stenosis. No evidence for an inflammatory origin could be found. In Case XI there was marked thickening and stiffness of the aortic valve near the bases of the cusps which was due to calcium deposit. Irregular, elevated, calcified areas projected into the sinuses of Valsalva. Atheromatous degeneration extended into the aorta as far as the arch. A few small nodules were noted on the auricular surface of the posterior leaflet of the mitral valve. No stenosis or insufficiency was present. The lesion was considered to be questionably of rheumatic origin.

One case of mitral disease (Case XIX) came to autopsy. This case typifies to our mind the findings we believe present in the 9 younger patients as regards the mitral valve. The mitral valve was seen to be typically stenosed with greatly thickened leaflets containing calcium. The aortic valve appeared normal. The lesion was considered to be of rheumatic origin. Cases XIII, XIV and XV would show in addition some involvement of the aortic valve by the rheumatic process as evidenced by the physical signs.

The gross and microscopic pathology resembled exactly the findings completely described by others[2,6,7,11,12,14,15,17,22,23]. The sections showed the usual areas of hyalinized connective tissue of the subendothelium with irregularly placed areas of calcification. In some cases this was confined to the valve leaflets. In marked cases this might extend beyond the base of the valve into its attachment in the annulus fibrosus.

Our pathological material certainly lends support to the theory of rheumatic etiology of calcified valves. It is impossible to say, however, from this material that previous attacks of rheumatism cause all of the calcified lesions that one encounters. Our series did not include a case of calcification in the annulus fibrosus, typified by the 4 older patients of the mitral group, but on examining old slides, cases were found in which this had occurred. In these cases the valve leaflets were entirely normal. Dr. Wolbach has aptly remarked in discussing the possible etiological factors in these cases that it was difficult to determine the cause of the fire by an examination of the ashes.

ROENTGENOSCOPY

A. *Technique.* As we have pointed out before, the calcification in the valves is most accurately as well as most easily demonstrated by roentgenoscopy. The technique is simple. One needs only to ask himself the question whether there are calcified areas inside the heart and then proceed to look for them. (1) Adequate preparation of the eyes is essential, of course, as in all roentgenoscopic examinations, but particularly when searching for these calcified areas inside the heart. We ordinarily stay fifteen minutes in a completely darkened room, but if the day is bright, or if the observer has been facing bright lights, twenty to thirty minutes is better. One can intersperse these cases during a series of gastrointestinal roentgenoscopies, when the eyes will be well sensitized and the pupils well accommodated. (2) A beam of rays of fairly high penetration is required, as one must look *through* the heart and not just study its outline by contrast as is usually done. We use a 4½ to 5 inch gap (70–75 kv. self-rectified) with 5 ma. of current which is usually sufficient. In very thick-chested or adipose patients, or in those with unusually large hearts, even more penetration and current may be better. (3) A very small aperture is necessary both to concentrate the attention and to cut down secondary radiation. The size of the field visible on the fluoroscopic screen should not be more than 4 or 5 cm. in diameter when searching for the smaller, less distinct areas of calcification. Many of the larger ones can easily be seen with a field large enough to include the whole heart shadow. With these three precautions, then, it is an easy matter to locate the auriculo-ventricular junction on the left border of the heart, and then search the area below and medial to this following a line 45° from the horizontal, which roughly corresponds to the auriculoventricular junction where the valves are located. It requires only a few seconds to search this region, looking for dark areas which show a dancing movement with each heart beat. (The same technique should be employed when looking for pericardial calcification, for calcified infarcts or aneurysms, and for calcified coronary arteries, only the areas searched are different.) (4) The position of the patient is important, as the dark areas of calcification can best be seen with the patient rotated so that the right shoulder is 15° to 20° forward, a modified right antero-oblique position. Deep inspiration with cessation of breathing also helps to differentiate the dancing intracardiac shadows from other shadows in the lung or mediastinum which move most with respiration, but which may show a slight transmitted pulsation. Pericardial and myocardial calcification show only slight movement.

B. *Movement of Calcified Valves.* These calcified valves uniformly demonstrate a high degree of mobility, moving toward the apex with systole and returning with

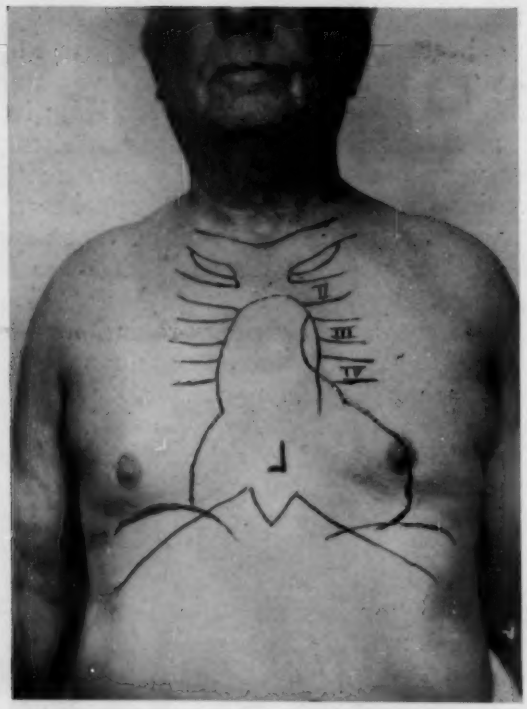

FIG. 1. Orthodiagram traced on patient's chest. Aortic stenosis with calcification (Case XII). Typical silhouette, valve low, almost in midline.

FIG. 2. Orthodiagram in mitral disease with calcification (Case XIV). Typical silhouette, valve low and well to the left.

diastole. The amount of movement is usually greater than that seen at the apex of the heart, and corresponds best to that seen on the posterior aspect of the heart in a marked left antero-oblique view. In only 2 of our cases was the heart so rapid or so irregular that we could not determine the relation of movement to the phase of the heart cycle. In several cases there was a double systolic movement, first downward toward the diaphragm and then toward the apex, with a return in a straight line to the

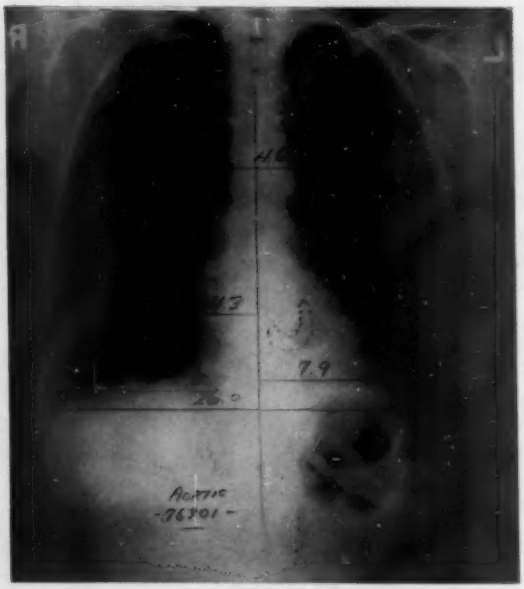

FIG. 3. Aortic stenosis with calcification. Seven-foot film, valve outlined from roentgenoscopic tracings (Case VII).

original position during diastole. This traced a roughly triangular course with the hypotenuse of the triangle formed during diastolic relaxation. In one patient (Case VII) where there were visible several separate distinct areas of calcification, a definite opening and closing was observed, the space between the calcified segments being widened during systole and narrowed during diastole, signifying to us that more than one leaflet of the valve was involved, and that the valve leaflets were still functioning, at least in part, in spite of the sclerosis.

C. *Location.* Most of the calcified aortic valves were located at the left border of the spine in the direct posteroanterior view, usually being hidden in whole or in part by the shadow of the spine and mediastinal contents. Anteroposteriorly they are usually deep in the heart about midway or just behind the center, as seen in an exaggerated left antero-oblique position. By comparison the calcified mitral valves are usually seen well to the left of the spine in the direct posteroanterior view, and lie in

Fig. 4. Same case as Figure 3, right antero-oblique position, short exposure.

the posterior third of the heart shadow in the exaggerated left antero-oblique view, sometimes so close to the posterior wall that they are thought at first to be in the pericardium. This is particularly true of those cases (XXII, XXIII, XXIV, XXV) in which we think the calcification is in the annulus fibrosus of the mitral valve. Figure 1 shows the usual site of the aortic valve and Figure 2 localizes the position of the mitral valve in the straight anterior view.* It is often difficult to demonstrate the lesser

Fig. 5. Same case as Figure 3, left antero-oblique position. Compare these with Figures 6, 7 and 8.

Fig. 6. Calcification in the mitral valve (?annulus fibrosus) (Case XXIV). Seven-foot films, valve outlined from roentgenoscopic tracings.

* These photographs were made by Miss Rowell after tracing the outline of the heart upon the patient's chest during roentgenoscopy. A very small fluoroscopic aperture was used, centered at each point on the heart outline as in making an orthodiagram and a skin pencil with a metallic lead sheath was used to mark each point. The ribs were sketched in afterward to show their relation to the heart outline. This tracing was of considerable value in teaching and in demonstrations, and was a great help in locating the murmurs and thrills in their relation to the position of the valves. A separate article is being prepared giving a more detailed discussion of the position of these valves in relation to heart outline, chest wall, and location of murmurs and thrills.

FIG. 7. Same case as Figure 6, right antero-oblique position, short exposure.

FIG. 8. Same case as Figure 6, left antero-oblique position, short exposure. Posterior limb of calcification near posterior border of heart.

degrees of calcification in the exaggerated left antero-oblique view, as we are looking through the long axis of the heart with the maximum amount of cardiac tissue superimposed.

In the markedly enlarged hearts of mitral disease, the calcified valve may be well to the left of the spine and much more toward the apex of the heart shadow than one would expect, suggesting that by far the greater part of the heart shadow is formed by the enormously dilated auricles.

FIG. 9. Calcification in mitral valve, small amount, short exposure, slight right antero-oblique position (Case xv).

D. *Confusing Shadows.* At roentgenoscopy there is nothing which simulates the dancing shadow of these calcified valves so far as we have seen. Areas of calcification in the mediastinum or lung overlying or behind the heart shadow can be rotated away from the heart in some position or other, and they move very little or not at all with the heart beat, showing their maximum movement upward and downward with respiration. Calcified areas in the pericardium usually can be located in the same manner, by rotating the patient gradually through a complete circle, or

even 180°, which usually is sufficient. Their motion is decidedly less than that of the valves in systole and diastole. The shape of the calcified areas may be of help in differentiation, those in the valves usually being C-shaped or J-shaped, while those in the pericardium are linear or branching. Calcified myocardial areas may be large and single or multiple and diffuse. We have not observed calcification in a tumor of the heart except after autopsy.

Fig. 10. Roentgenogram of heart post mortem. Upper left wire at attachments of aortic valve, calcification in valve leaflets, in bead-like strings (Case xi). Also slight calcification in mitral valve and in coronary arteries. Note that ventricles form most of heart shadow, compared to Figure 11, where auricles predominate.

Fig. 11. Roentgenogram of heart post mortem. Fine wires at attachments of valves, lower-mitral, upper-aortic. Metal strip in narrow orifice of mitral valve (Case xix).

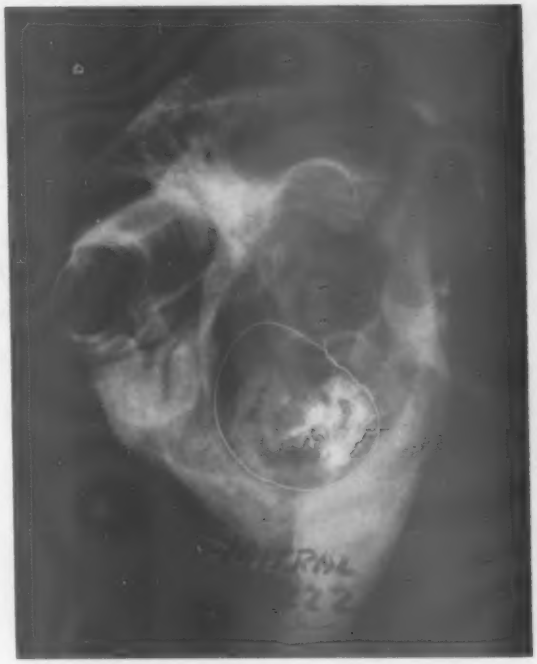

Fig. 12. Same case as Figure 11, viewed from above. Calcification almost entirely in posterior leaflet of mitral valve.

ROENTGENOGRAPHY

On the films the most confusing shadows are those of the calcified costal cartilages so common in older people. These may be so extensive and so marked that it is impossible to be certain of the shadow of calcified valves which were seen clearly during roentgenoscopy. Here, too, calcified glands and calcified areas in the lung may be con-

fused with the shadows cast by the calcified valves. In our department we depend upon the roentgenoscopic examination for the demonstration of the presence of calcification, using the film method only to check the amount and distribution of the calcification and to furnish a permanent record for demonstration. Tracings of the heart shadow and of the areas of calcification may be made at roentgenoscopy either upon washed films or directly upon the patient's chest, as noted above. The latter method is not of value in women, as the breasts interfere with the accurate outlining of the heart shadow. Before making roentgenograms we mark the spot on the patient's chest where the valve is best seen, both front and back, as in locating foreign bodies. This enables the technician to use a small cone, and, by getting the two points in line, to duplicate the position in making films. For the latter, speed is essential, the exact speed depending upon the heart rate, the faster the heart rate the shorter the exposure must be. We have obtained excellent roentgenograms in one-tenth of a second, but more commonly one-thirtieth of a second has been necessary. Our maximum milliamperage is 200, distance 30 inches, using fast screens and speed films, and a "dental cylinder" directed at the spots marked on the patient's skin. It should be easier to demonstrate these calcified valves with a 1000-milliampere machine. An elaborate relay such as that described by McPhedran and Weyl[16] is not necessary provided a sufficiently short exposure can be made which will penetrate the heart shadow. A Potter-Bucky diaphragm such as that made by Lysholm may be used advantageously in roentgenoscopy, but it requires almost double the current, and for this reason should not be of advantage in roentgenography where speed is essential. The small cone (diam. 7.5 cm., length 25 cm.) in fact cuts down the secondary rays and thus acts like the Potter-Bucky grid. Obviously the film must be over-exposed so that the rays will go through the heart, showing it only as a gray background with the white areas of calcification standing out clearly. These are usually finely granular in appearance and closely packed, although sometimes separate masses may be seen. A roentgenographic study of hearts removed at postmortem examination will give one a good idea of what to expect.

CASE SUMMARIES OF AORTIC DISEASE

CASE I. F.T.[5] (X-ray No. 67360), an engineer, aged fifty-three, entered the hospital complaining of shortness of breath and nervousness of five years' duration. He had had rheumatic fever at twelve years of age. Clinically he showed a slightly enlarged heart. The heart sounds were of moderate intensity and the first sound was obliterated by a blowing systolic murmur heard all over the precordium but loudest at the base in the aortic area where a thrill was palpable. There was a blowing diastolic murmur at the base. The blood pressure was 120/65. The lungs showed slight dullness at both bases posteriorly with rather loud crackling râles. The legs showed slight pitting edema. From the clinical signs aortic stenosis with calcification of the aortic valve was predicted.

Roentgen examination on February 27, 1931, showed the heart to be moderately enlarged, chiefly to the left. The aorta was tortuous. The measurements were: median right, 4.8 cm.; median left, 11.0 cm.; great vessels, 6.0 cm.; internal diameter of chest, 29.0 cm. Roentgenoscopy showed multiple areas of calcification in the region of the aortic valve which moved toward the apex of the heart with systole and away from it in diastole, the total excursion being about 0.5 cm. The beat was regular and of good quality, and not exaggerated as in aortic insufficiency.

Diagnosis: Valvular disease, combined chronic cardiac; aortic stenosis and insufficiency; calcareous aortic valvular disease.

CASE II. S.S. (X-ray No. 69918), a carpenter, aged fifty-six, entered the hospital complaining of a severe cough and dyspnea on slight exertion for six months. The past history revealed a fever of unknown origin in childhood, but no specific history of rheumatism could be obtained. Clinically the patient showed an enlarged heart. The rhythm was completely irregular. There were no murmurs and no thrills. The first sound was split at the apex. The blood

pressure was 160/104. Cardiac decompensation was marked. (The earlier records of this patient, when the heart rhythm was regular, revealed that a presystolic rumble had been heard at the apex.)

Roentgen examination on November 1, 1932, showed the heart to be enlarged both to the right and left with no fullness in the region of the left auricle. Roentgenoscopy showed scattered irregular areas of calcification just to the left of the midline in the region of the aortic valve moving toward the apex with each systole. The patient died but autopsy was not permitted. (This patient had been roentgenoscoped twice before in this department in 1931 by assistants who did not look for calcified valves and who did not therefore find them.)

Diagnosis: Valvular disease, combined chronic cardiac, mitral stenosis and insufficiency; calcareous aortic valvular disease; auricular fibrillation; bronchopneumonia.

Case III. E.A. (X-ray No. 76922), a cook, aged fifty-six, entered the hospital complaining of shortness of breath for two months. He had had rheumatic fever at fourteen years of age. Clinically he showed an enlarged heart. The rhythm was totally irregular. There were systolic and diastolic murmurs at the base and at the apex. There was a systolic thrill at the base. The blood pressure was 180/95. There were slight signs of cardiac insufficiency.

Roentgen examination disclosed no areas of intracardiac calcification but these were suspected clinically. There was definite cardiac enlargement both to the right and left with some fullness in the left auricular region. The measurements were: M.r., 6.8 cm.; M.l., 10.2 cm.; G.V. 5.7 cm.; Int. Dia., 29.8 cm.

The patient died suddenly. Post-mortem roentgen examination of the heart revealed calcification in the coronary arteries and in the aortic valve cusps, the latter forming a finely mottled irregular mass 1.5×3.0 cm. in size, limited to the two posterior cusps and not extending onto the wall of the aorta or into the myocardium.

At autopsy the heart weighed 680 grams. The tricuspid and pulmonary valves appeared normal. The *mitral valve* admitted two finger tips and was considered to be slightly stenosed. The valve leaflets were shortened and moderately thickened at the margins. There were no vegetations or atheromatous plaques on the leaflets. The chordae tendinae were hypertrophied and shortened. There was slight fusion of the mitral valve cusps. The valve was not rigid but had slight impairment in its competence. The *aortic valve* showed moderate stenosis and marked insufficiency. The cusps were thickened, rigid and hardened. At the junction of the right and left posterior aortic cusps there was a warty calcified mass approximately 8 mm. in diameter. The sclerotic changes were confined almost entirely to the cusps and their bases. The sinuses of Valsalva were uninvolved. The corpora Arantii were thickened and nodular. The coronary arteries showed marked sclerosis and the right coronary artery was occluded. Microscopically a slight infiltration of lime salts was noted at the base of mitralvalve.

Diagnosis: Valvular disease; combined chronic cardiac; aortic stenosis and insufficiency, marked; calcareous aortic valve disease; mitral stenosis and insufficiency, slight; coronary sclerosis, marked; cardiac infarction; myocardial fibrosis; arteriosclerosis, generalized.

Case IV. F.C. (X-ray No. 76098), a male clerk, aged fifty-nine, entered the hospital complaining of dyspnea on exertion of two months' duration. There was no past history of rheumatic fever or allied conditions obtainable. Clinically his heart was enlarged. There was a loud systolic murmur in the aortic area transmitted upward and accompanied by a thrill. There was no diastolic murmur heard. The blood pressure was 112/100. The liver was palpable and tender. There were moist râles at both bases of the lungs. There was edema of the ankles. There were marked evidences of Paget's disease.

Roentgen examination on December 20, 1932, showed definite cardiac enlargement downward and to the left with no mitral fullness. The aorta was not enlarged. The measurements were: M.r., 4.5 cm.; M.l., 12.6 cm.; G.V., 5.6. cm.; Int. Dia. 29.4 cm. Roentgenoscopy showed a vigorous ventricular pulsation, but a small aortic pulsation, the latter definitely less than normal. There was an irregular mass of calcification deep in the heart at the left border of the spine measuring 2.5×4 cm. in size and shaped like an inverted "C." It moved sharply toward the apex of the heart with systole. This was in the region of the aortic valve.

Diagnosis: Valvular disease, chronic cardiac, aortic stenosis; calcareous aortic valvular disease; Paget's disease.

Case V. E.B. (X-ray No. 75945), a housewife, aged sixty, entered the Out-Door Department

complaining of a toothache. There was no past history of rheumatic fever or allied conditions obtainable. Clinically her heart was enlarged. There was a systolic murmur and thrill at the base. There was no diastolic murmur. The blood pressure was 200/110. There were no signs of cardiac insufficiency.

Roentgen examination on December 7, 1932, showed the heart to be enlarged to the left with a rounded, blunt left ventricle. The aorta was tortuous and there was marked calcification in the arch. The measurements were: M.r., 4.3 cm.; M.l., 8.7 cm.; G.V., 5.6 cm.; Int. Dia., 24.2 cm. Roentgenoscopy showed a regular sustained beat with calcification deep in the heart just to the left of the spine in the aortic valve.

Diagnosis: Valvular heart disease, chronic cardiac, aortic stenosis; calcareous aortic valvular disease.

CASE VI. W.A. (X-ray No. 70214), a male music teacher, aged sixty-three entered the hospital complaining of substernal burning and eructation of gas for years, worse in the past two months. There was no past history of rheumatism or allied conditions. Clinically the patient showed a slightly enlarged heart with a loud systolic murmur over the precordium, loudest at the base where a systolic thrill was noted. No diastolic murmur was heard. The blood pressure was 160/110. Roentgen examination showed a complete pyloric obstruction due to an annular carcinoma. This was confirmed at operation and the carcinoma was resected, with uneventful recovery.

During a follow-up examination of the stomach on November 16, 1931, roentgenoscopy showed calcification deep in the heart in the region of the aortic valve, the calcified areas moving toward the apex with systole. The heart showed marked rounding and blunting of the left ventricle. There was marked tortuosity of the aorta. The measurements were: M.r., 6.1 cm.; M.l., 9.2 cm.; G.V., 7.2 cm.; Int. Dia., 29.2 cm.

The patient was admitted to the hospital two months later because of decompensation. He died one month later but autopsy permission was denied.

Diagnosis: Valvular disease, chronic, cardiac, aortic stenosis; calcareous aortic valvular disease; carcinoma of the stomach with metastases.

CASE VII. L.E. (X-ray No. 76301), a housewife, aged sixty-eight, entered the Out-Door Department complaining of gas after meals for one month and increasing dyspnea for two years. There was no past history of rheumatic fever or allied conditions obtainable. Clinically there was no enlargement of the heart. There was a rough systolic murmur heard all over the precordium, loudest at the base. There was no thrill or diastolic murmur noted. The blood pressure was 110/68. The liver was slightly enlarged but there were no other signs of cardiac failure.

Roentgen examination on January 9, 1933, showed no enlargement of the heart or abnormality in contour. The measurements were: M.r., 4.3 cm.; M.l., 7.9. cm.; G.V., 4.6 cm.; Int. Dia., 26.0 cm. Roentgenoscopy showed a large, dense, irregular area of calcification deep in the heart overlying the left edge of the spine in the anteroposterior view and in the posterior third of the heart in the region of the annulus fibrosus. The calcification covered an area 3.5 $\times$ 4 cm. in size and roughly was annular and in three segments. The left anterior segment moved most, and there was definite opening and shutting of the space between the segments synchronous with the heart beat.

Diagnosis: Valvular disease, chronic cardiac, aortic stenosis; calcareous aortic valvular disease.

CASE VIII. G.C. (X-ray No. 20767), a watchman, aged sixty-nine entered the hospital complaining of severe mid-epigastric pain for ten hours. He gave a history of chorea at nine years of age. Clinically he showed a slightly enlarged heart and a systolic thrill at the base. There was a loud harsh systolic murmur heard over the precordium but most marked at the base. A faint early diastolic murmur was heard along the left sternal margin. The blood pressure was 180/80. There were no signs of cardiac failure. The abdomen was boardlike with generalized tenderness.

Seven months previously the patient had been in the hospital complaining of upper abdominal pain. Roentgen examination then on March 3, 1931, showed definite cardiac enlargement, more to the left than to the right. The measurements were: M.r., 4.9. cm.; M.l., 10.8 cm.; G.V., 6.0 cm.; Int. Dia., 29.1 cm. The aorta was tortuous. There were three distinct areas of intracardiac calcification seen in the position of the aortic valve.

The patient was operated upon and a gangrenous ruptured gallbladder was found causing the generalized peritonitis present. Bronchopneumonia developed and the patient died.

Post-mortem roentgen examination of the heart showed multiple irregular separate areas of calcification involving all three aortic cusps and the anterior mitral cusp.

At autopsy the heart weighed 460 grams. The heart was roughly triangular in shape and enlarged chiefly as the result of left ventricular hypertrophy. The tricuspid and pulmonary valves were normal. The anterior leaflet of the *mitral valve* showed patchy, firm, raised, yellowish-gray thickenings which were irregular in shape, hard, and when cut, were found to be calcified. The calcification extended from the mid-portion of the mitral ring over the anterior cusp down through the leaflet as far as the free margin, and was there more marked and extensive than at any portion of the leaflet. The posterior leaflet and mitral ring above the valves were free from calcified plaques. The *aortic valve* showed an extensive degree of calcification which was associated with definite stenosis. All three leaflets were thickened, rigid, and stood out from the wall of the aorta for a distance varying from 4 to 6 mm. In the valves there were numerous irregular, raised, extremely hard, calcified masses. The calcification was most marked in the anterior aortic leaflet which was seen in one place to measure 6 mm. in thickness. The calcification stopped rather abruptly at the attachment of the leaflets to the aortic wall and only a few small, round, calcified patches were found in the sinuses of Valsalva. About the aortic ring, at the upper margin of the sinuses there was a thin ring of small calcified plaques which varied from 1–2 mm. in diameter. When viewed from above the aortic orifice was seen to be a narrow three-sided slit measuring 7 mm. at its widest portion.

Diagnosis: Valvular disease, combined chronic cardiac, aortic stenosis and insufficiency; aortic valvular calcification; mitral calcification (anterior leaflet); mitral insufficiency with bronchopneumonia and generalized peritonis as causes of death.

Case ix. W.T. (X-ray No. 62144), a lawyer, aged seventy, entered the hospital because of mental changes of three weeks' duration. The history was obtained from his wife and no past history of rheumatic fever could be disclosed. Clinically he showed an enlarged heart. There was a systolic murmur heard over the entire precordium becoming loud, rough and high-pitched at the base where a systolic thrill was felt. No diastolic murmur was heard. The blood pressure was 140/80. There were moist râles in the bases and the liver was palpable 3 cm. below the costal margin.

Roentgen examination on September 19, 1932, revealed definite cardiac enlargement chiefly to the left with a prominent and rounded left ventricle. The aorta was tortuous. The measurements were: M.r., 6.2 cm.; M.l., 10.2 cm.; G.V., 6.1 cm.; Int. Dia., 30.0 cm. Roentgenoscopic examination showed an irregular mass of calcification in the region of the aortic valve. This moved toward the apex with systole. There was marked calcification in the arch of the aorta.

Diagnosis: Valvular disease, chronic cardiac, aortic stenosis; calcareous aortic valvular disease.

Case x. H.W. (X-ray No. 54714), a nurse, aged seventy, complained of high blood pressure for sixteen years. She gave a history of severe "growing pains" in childhood, yearly attacks of tonsillitis, and severe rheumatism at forty-seven years of age. Clinically she showed an enlarged heart. There was a blowing systolic murmur heard over the precordium getting very rough at the base where a short thrill was felt. There was no diastolic murmur. The blood pressure was 190/90. There were no signs of cardiac failure. The heart measurements from a 7-foot film were: M.r., 5.3 cm.; M.l., 8.5 cm.; G.V., 5.7 cm.; Int. Dia., 22.0 cm.

Roentgenoscopic examination on May 2, 1932, showed a large U-shaped area of intracardiac calcification which moved toward the apex with systole. It appeared nearer the apex and more posterior than the expected position of the aortic valve, but its location was deeper in the heart than pericardial calcification would be. Fast films confirmed this finding showing the calcified area forming three-quarters of a ring, measuring 4 cm. in diameter and lying 1.5 cm. distant from the posterior pericardium.

Diagnosis: Valvular disease, chronic cardiac, aortic stenosis; calcareous aortic valvular disease.

Case xi. C.W. (X-ray No. 66786), a cleaner, aged seventy-two, was brought to the hospital because of unconsciousness of six hours' duration. There was no past history of rheumatic fever or allied conditions obtainable. Clinically his heart was enlarged and there was a slight systolic thrill at the base. A loud blowing systolic murmur was heard all over the precordium which became harsh over the aortic area and was transmitted into the vessels of the

neck. There was no diastolic murmur auscultated. The blood pressure was 180/96. The liver was easily palpable and there were moist râles at the bases of the lungs.

Roentgen examination at this admission was not possible. Eleven months previously a 7-foot film of the heart showed cardiac enlargement both to the right and left. The measurements were: M.r., 6.1 cm.; M.l., 10.6 cm.; G.V., 8.1 cm.; Int. Dia., 31.0 cm. The aortic shadow appeared widened and tortuous.

The patient died without regaining consciousness. On December 15, 1932, before the autopsy, films of the chest were taken and these showed that calcification was present in the region of the aortic valve. Post-mortem roentgen studies of the heart showed multiple small dense areas of calcification in the three aortic valve cusps and a small amount on the wall of the aorta and a third area in the posterior mitral cusp. The areas in the aortic cusps were dense, finely granular and presented an appearance like several strings of beads.

At autopsy the heart weighed 740 grams. The tricuspid and pulmonary valves were normal. On the anterior leaflet of the *mitral valve* there was a yellowish area of atheromatous degeneration containing, as far as could be determined, no calcium. There was a small area of calcium deposition in the substance of posterior leaflet. There was no evidence of stenosis or insufficiency. The *aortic valve* was exposed from above. The orifice admitted the tip of one small finger. The valve cusps were moderately rigid due to a deposition of calcium. The free margins of the cusps were fairly pliable. The deposition of calcium with thickening of the valve cusps was, for the most part, adjacent to the bases of the cusps or in the mid-portion. The elevated, irregular, calcified areas projected into the sinuses of Valsalva and resembled healed vegetations. The calcification above the valve cusps was of the type due to atheromatous degeneration and was continued so as to involve the intima of the arch of the aorta.

Diagnosis: Valvular disease, chronic cardiac, aortic stenosis; calcareous aortic valvular disease; calcareous mitral valve disease; cardiac hypertrophy and dilatation; questionable healed rheumatic heart disease. The cause of death was a thrombosis of the left internal carotid and middle cerebral arteries.

CASE XII. G.S. (X-ray No. 19842), a printer, aged seventy-two, entered the hospital complaining of shortness of breath for two months. He was seen when fifty-six years old and treated for general paresis, the symptoms of which did not progress after that time. There was no history of rheumatic fever or allied conditions. Clinically he showed an enlarged heart. There was a systolic murmur at the apex but loudest at the base where there was a systolic thrill. There was no diastolic murmur. The blood pressure was 115/50. There were no signs of cardiac failure not accounted for by the marked secondary anemia present.

Roentgen examination on March 7, 1933, showed definite cardiac enlargement. The aorta was tortuous. The measurements were: M.r., 5.4 cm.; M.l., 10.7 cm.; G.V., 7.0 cm.; Int. Dia., 30.5 cm. There were multiple small areas of calcification deep in the heart close to the midline of the sternum. These showed a constant dancing movement toward the apex with systole. Their excursion was greater than the excursion of the apex of the heart. The calcified areas were in the region of the aortic valve.

Diagnosis: Valvular disease, chronic cardiac, aortic stenosis; calcareous aortic valve disease; anemia, secondary; general paresis, arrested. Subsequent examinations showed the cause of the secondary anemia to be an inoperable carcinoma of the stomach.

CASE SUMMARIES OF MITRAL DISEASE

CASE XIII. A.S. (X-ray No. 74692), a housewife, aged twenty-four, entered the hospital because of hemoptysis. She had had attacks of tonsillitis but no history of rheumatism or chorea could be obtained. Clinically she showed signs of a pulmonary abscess which was confirmed by roentgen examination. Her heart was enlarged. There were systolic and diastolic murmurs at the apex. There was a diastolic murmur at the base. There was no thrill at the apex. The blood pressure was 118/50. There were no signs of cardiac failure. The patient was well enough for a thorough roentgenoscopic examination on October 14, 1932, and the heart was noted as enlarged with fullness on the left border in the region of the left auricle. A small area of calcification was noted in the region of the mitral valve.

The pulmonary abscess healed under medical treatment and the patient was discharged.

Diagnosis: Valvular disease, combined chronic cardiac, mitral stenosis and insufficiency, aortic insufficiency; calcareous mitral disease; abscess of the lung.

CASE XIV. H.A. (X-ray No. 75905), a mail

clerk, aged thirty-three, entered the hospital complaining of pounding of the heart for four years. The patient had had tonsillitis several times, chorea at ten years, and rheumatic fever at seventeen years. Clinically he showed an enlarged heart and slight precordial bulging. A loud blowing systolic murmur obliterated the first sound and a rumbling diastolic murmur followed an indistinct second sound at the apex. There were systolic and diastolic murmurs at the base. A diastolic apical thrill was felt. The rhythm was grossly irregular. The blood pressure was 115/75. There were no signs of cardiac failure. Roentgen examination on December 6, 1932, showed definite cardiac enlargement, both to the right and left. There was marked fullness of the left auricle which projected backwards into the posterior mediastinum, displacing the esophagus backward. Roentgenoscopy showed calcification well to the left of the spine, deep in the heart opposite the auriculoventricular groove, in the area of the mitral valve, with sharp movements toward the apex with systole.

Diagnosis: Valvular heart disease, combined chronic cardiac, aortic insufficiency, mitral stenosis and insufficiency; calcareous mitral disease; auricular fibrillation.

Case xv. S.J. (X-ray No. 73844), a shoe salesman, aged thirty-six, entered the hospital complaining of pain in the left upper quadrant for one day. He had had rheumatic fever at eighteen years and had been under observation in this hospital for ten years. Clinically he showed an enlarged heart with systolic and diastolic murmurs at the apex and base. There was a systolic thrill at the base and at the apex. The rhythm was absolutely irregular. The blood pressure was 116/94. The liver was palpable but there were no signs of cardiac insufficiency. A roentgen examination for the first time on June 24, 1932, showed marked cardiac enlargement both to the right and left with considerable prominence of the left auricle which projected back into the mediastinum and extended to the right of the midline. The esophagus was displaced to the right. The measurements were: M.r., 8.5 cm.; M.l., 10.9 cm.; G.V., 4.2 cm.; Int. Dia. chest, 25.6 cm. Roentgenoscopy showed a definite irregular area of calcification 1.5×2.5 cm. in size in the region of the mitral valve. This moved toward the apex with systole.

Diagnosis: Valvular disease, combined chronic cardiac with mitral stenosis and insufficiency and aortic insufficiency; calcareous mitral disease; auricular fibrillation; pleurisy, acute fibrinous.

Case xvi. M.D. (X-ray No. 75517), a female clerk, aged thirty-eight, entered the Out-Door Department complaining of marked fatigue. She had had rheumatic fever three times at eight, eleven and fifteen years of age. Clinically she showed systolic and diastolic murmurs at the apex. There were no murmurs at the base. The rhythm was regular. No thrills were palpated. The blood pressure was 130/90. There were no evidences of cardiac failure. Roentgenoscopic examination on November 5, 1932, showed a small area of calcification in the mitral valve, moving toward the apex with each systole.

Diagnosis: Valvular disease, chronic cardiac, mitral stenosis and insufficiency; calcareous mitral disease.

Case xvii. H.C. (X-ray No. 76415), a male clerk, aged thirty-eight, entered the hospital complaining of shortness of breath and palpitation for two years. He had had rheumatic fever at twenty-seven years of age. Clinically he showed both systolic and diastolic murmurs at the apex. There were no basal murmurs or thrills over the precordium. The rhythm was grossly irregular. The blood pressure was 130/75. The liver was markedly enlarged and there were râles at the lung bases. Roentgen examination on January 17, 1933, showed marked cardiac enlargement, both to the right and left with dilatation of both auricles. Roentgenoscopy showed a J-shaped area of calcification deep in the heart overlying the left border of the spine with the dancing movements at each cardiac contraction, located in the region of the mitral valve.

Diagnosis: Valvular disease, chronic cardiac, mitral stenosis and insufficiency; calcareous mitral disease; auricular fibrillation.

Case xviii. H.B. (X-ray No. 75778), a shoe salesman, aged forty-two, entered the hospital complaining of swelling of the legs for four months. He had had rheumatic fever at seventeen and again at twenty years of age. Clinically he showed marked cardiac enlargement. There were systolic and diastolic murmurs at the apex, but not heard at the base. There were no thrills palpated. The rhythm was grossly irregular. The blood pressure was 145/100. There was marked edema of the ankles, the liver was palpable, and there were râles at both bases. Roentgen examination on November 25,

1932, showed marked cardiac enlargement both to the left and right with definite fullness in the region of the left auricle and apparent dilatation of the right auricle. The measurements were: M.r., 7.7 cm.; M.l., 13.5 cm.; G.V., 6.0 cm.; Int. Dia., 29.6 cm. Roentgenoscopy showed an irregular area of calcification inside the heart, well to the left of the spine and well posterior, moving toward the apex with each systole.

Diagnosis: Valvular disease, chronic cardiac, mitral stenosis and insufficiency; calcareous mitral valvular disease; auricular fibrillation.

CASE XIX. J.E. (X-ray No. 75222), a machinist, aged forty-four, entered the hospital complaining of dyspnea and precordial pain of five and one-half years' duration. He had had rheumatic fever at twenty-two years of age. Clinically he showed a slightly enlarged heart. The heart sounds were of good quality. There was a mid-diastolic rumble at the apex accompanied by a thrill. A faint systolic murmur followed the first sound. There were no murmurs at the base. The rhythm was grossly irregular. The blood pressure was 118/70. There were a few crackles at both bases but otherwise no signs of cardiac failure. Roentgen examination on October 18, 1932, showed the heart slightly enlarged in the transverse diameter with definite prominence in the region of both auricles which projected backward into the posterior mediastinum, displacing the esophagus backward and to the right. The measurements were: M.r., 5.9 cm.; M.l., 8.2 cm.; G.V., 4.4 cm.; Int. Dia. chest, 27.6 cm. Roentgenoscopy showed definite irregular nodular calcification deep in the heart, probably in the mitral valve. This moved toward the left and toward the apex with systole. The patient died twenty-six hours after cardiotomy and valvulotomy. Postmortem films of the heart showed a triangular mass of calcium 2.2×2.1×1.7 cm. in size in the posterior leaflet of the mitral valve and extending into the myocardium. The calcium deposit was finely granular and irregular, not beaded or in streaks.

At autopsy the heart weighed 620 grams. It was fixed after the method of T. Lewis and windows cut so as to give a view of the valves. The auricles constituted roughly two-thirds of the specimen. The left ventricle appeared normal. The left auricle was capacious. The mitral valve measured 3×3.5 cm. Its leaflets were greatly thickened and calcareous at the posterior limits. The orifice was 1 cm. long by 2 mm. wide, fish-mouthed and sclerosed, a typical completely stenotic valve. The margins of the valve leaflets were firm, irregular and calcified.

Diagnosis: Valvular heart disease, combined chronic cardiac, mitral stenosis and insufficiency; calcification of the mitral valve; cardiac hypertrophy and dilatation; fibrinous pericarditis; pulmonary arteriosclerosis; pulmonary congestion and edema; bronchopneumonia.

CASE XX. C.B. (X-ray No. 55413), a housewife, aged fifty-two, entered the hospital complaining of a dull pain over the precordium, in the left axilla, and left upper quadrant of three days' duration. Through language difficulties no definite history of rheumatism could be obtained but she did remember tender swollen ankles as a child. Clinically she showed an enlarged heart with systolic and diastolic murmurs at the apex. There were no murmurs at the base. The rhythm was grossly irregular. The blood pressure was 118/78. There were slight signs of cardiac failure. During roentgen examination of her gastrointestinal system on November 3, 1932, roentgenoscopy showed an enlarged heart with intracardiac calcification almost 5 cm. to the left of the midline and located posteriorly in the heart. This moved toward the apex with systole and was in the region of the mitral valve. Subsequently this patient had numerous embolic phenomena interpreted as coming from the heart.

Diagnosis: Valvular disease, combined chronic cardiac, mitral insufficiency and stenosis; calcareous mitral valvular disease; auricular fibrillation; infarct of lungs, kidneys, spleen, right cerebrum.

CASE XXI. J.M. (X-ray No. 56352), a caterer, aged fifty-six, entered the hospital complaining of pain in the left back and groin of five weeks' duration. He had had rheumatic fever at twenty years of age. Clinically he showed an enlarged heart. Both systolic and diastolic murmurs were heard at the apex. No murmurs were heard at the base. There was no thrill. The rate was grossly irregular. The blood pressure was 165/80. There was no evidence of cardiac failure. Roentgen examination on December 19, 1932, showed an enlarged heart with prominences in the region of the right and left auricles. The measurements were: M.r., 5.5 cm.; M.l., 10.6 cm.; G.V., 6.2 cm.; Int. Dia., 28.3 cm. Roentgenoscopy showed definite irregular areas of calcification deep in the heart to the left of the spine in the region of the mitral valve. Films showed other doubtful areas of calcification.

Diagnosis: Valvular disease, chronic cardiac, mitral stenosis and insufficiency; calcareous mitral valvular disease; renal calculus; cholelithiasis; auricular fibrillation.

Case XXII. E.D. (X-ray No. 75774), a constable, aged fifty-eight, entered the hospital complaining of shortness of breath for nine months. The patient had had scarlet fever in childhood. There was no history of tonsillitis, chorea or rheumatism. Clinically the patient had an enlarged heart. The heart sounds were faint and there were no murmurs. The rhythm was grossly irregular. There were no thrills. The blood pressure was 105/60. The liver was enlarged. There was free fluid in the chest. A roentgen examination on November 25, 1932, confirmed the presence of fluid in the chest cavities. The heart was enlarged to the left and right, was irregular in outline and indistinct. Roentgenoscopy showed a rapid, completely irregular beat with marked prominence of the left auricle posteriorly. An irregular mass of calcification was seen well posterior in the heart, 1×3 cm. in size and well to the left of the spine. This moved toward the apex with systole.

Diagnosis: Chronic myocarditis; auricular fibrillation; calcification of the annulus fibrosus of the mitral valve.

Case XXIII. R.N. (X-ray No. 4371), a housewife, aged seventy-two, entered the Out-Door Department complaining of epigastric distress and dyspnea on exertion. She had been under observation at this hospital for seventeen years. She gave no history of rheumatic fever or allied conditions. Clinically her heart was enlarged There was a rough systolic but no diastolic murmur heard at the apex. The heart sounds were very faint at the base where no murmurs were heard. There was no thrill palpated. The blood pressure was 190/74. There were no signs of cardiac failure. On June 7, 1932, during a gastrointestinal examination, a definite area of calcification was seen in the heart roentgenoscopically near the posterior border just to the left of the spine in the approximate region of the auriculo-ventricular septum. This area of calcification was shaped like a "C" and it moved definitely toward the apex with each systole.

Diagnosis: Calcification in the annulus fibrosus of the mitral valve; chronic myocarditis.

Case XXIV. P.M. (X-ray No. 76195), a retired police officer, aged seventy-six, entered the Out-Door Department complaining of precordial pain and dyspnea for two years. There was no past history of rheumatism, tonsillitis or chorea but he had had severe growing pains as a child. Clinically he showed no cardiac enlargement, There was a rough systolic murmur over the precordium but no diastolic murmur. There was no precordial thrill. The rhythm was regular. The blood pressure was 120/65. There were no evidences of failure except a slight enlargement of the liver. Roentgen examination of his heart on December 30, 1932, showed the size to be within normal limits. The measurements were: M.r., 4.8 cm.; M.l., 7.6 cm.; G.V., 5.8 cm.; Int. Dia., 31.0 cm. Roentgenoscopy showed a large C-shaped area of calcification deep in the left side of the heart, the posterior limb being only 1.5 cm. from the posterior surface of the heart. This lay just at the left border of the spine and moved toward the apex with systole. It was thought to be in the annulus fibrosus of the mitral valve.

Diagnosis: Valvular heart disease, chronic cardiac (?), mitral insufficiency; calcification in the annulus fibrosus of the mitral valve; angina pectoris.

Case XXV. L.P. (X-ray No. 75488), a housewife, aged seventy-seven, entered the Out-Door Department complaining of weakness, backache and heart consciousness for years. There was no past history of rheumatic fever or chorea but she did remember having had severe growing pains as a child. Clinically she showed a slightly enlarged heart. There was a systolic murmur heard over the precordium loudest at the apex. There was an occasional sound heard in diastole but the heart rate was only 44, due to a normal bradycardia. The rhythm was regular. There was no thrill palpated. The blood pressure was 148/70. Slight signs of cardiac insufficiency were noted.

Roentgen examination on November 3, 1932, showed definite cardiac enlargement. There was a dense area of calcification, intracardiac in position, to the left of the midline below the medial end of the 5th cartilage located well posterior and close to the pericardium. This calcium deposit was crescentic in appearance, concave upward and moved definitely toward the apex with systole. At the time this was considered to be pericardial calcification. Further studies, however, showed that the calcification was in the heart substance, at one point only 1.5 cm. from the posterior surface of the pericardium. It was finally decided that the calcification was probably in the annulus fibrosus of the mitral valve.

Diagnosis: Calcification of the annulus fibrosus of the mitral valve; chronic myocarditis; generalized severe arteriosclerosis.

SUMMARY

A brief historical survey is presented covering the previously reported cases of aortic and mitral valvular disease with calcifica-

tion demonstrable by roentgen examination.

Twelve cases of aortic stenosis with calcification are reported, ten of which were demonstrated roentgenographicall yin vivo.

Thirteen cases of mitral disease with calcification are reported, all of which were demonstrated roentgenographically in vivo.

The clinical aspects of these cases are discussed.

The existing views on the etiology and pathology of calcified valves are given briefly, reviewing the literature.

The technique of roentgenoscopy and roentgenographic methods for demonstrating these calcified valves are presented.

The case histories are briefly summarized.

CONCLUSIONS

1. The roentgen-ray visualization roentgenoscopically and roentgenographically of calcified heart valves during life is possible with present-day roentgen apparatus.

2. Aortic stenosis with calcification is a common finding in older patients. Calcification in the mitral valve leaflets is accompanied by definite signs of mitral stenosis. Calcification in the annulus fibrosus of the mitral valve, at least, may be entirely unrelated to disease of the cusps and produce no cardiac symptoms.

Addenda 1. Since this article was written a case report of a calcified mitral valve in a boy, aged fourteen, has appeared in *Radiography and Clinical Photography*, July, 1933, *9*, 10, by Paul A. Bishop.

2. At the present date (July 25, 1933) we have in our records 39 cases of calcification in the valves of the heart, including the 23 cases reported in this article. Of these there are 19 in the mitral valve or mitral annulus fibrosus, and 20 in the aortic valve, all demonstrated roentgenographically in vivo.

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Vol. XXX, No. 3

THE GENEALOGY OF THE ROENTGEN RAYS*

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Clevevand Clinic Foundation
CLEVELAND, OHIO

VOLTA was a very critical and accurate experimenter. Even as a boy he had carefully built many instruments for measuring electricity. One of these was an electroscope with a straw leaf and a condenser called a "multiplicator." Because of these experiments in his youth he acquired excellent exerimental technique which later served him well in his important work. At first Volta was completely convinced of the correctness of Galvani's deductions, but he soon found that the source of the electricity could not be solely within the animal tissue. In one experiment he exposed a piece of nerve from a frog's leg and connected the wires without touching muscle, thus showing that an electrical effect could also be produced with one type of tissue alone. Supplementing these observations by many other experiments, he soon came to the conclusion that the source of the current was not animal electricity but originated in the metals themselves. He found in 1798 that electricity is created whenever two different conductors are placed in contact. He then replaced the term "animal electricity" by "metal electricity." These different theories of Volta and Galvani led to a sharp controversy between the two scientists which was only interrupted by Galvani's death. Going a step further, Volta divided the solid and liquid conductors into conductors of the first degree, including metal and carbon, and conductors of the second degree, or electrolytes. He measured the electrical charges with an instrument developed from the electroscope of his boyhood, the sensitivity of which he could vary within wide limits by means of a condenser arrangement. The brilliant deductions that followed Volta's experiments, especially the definition of the Volta range of potentials, are classical.

Volta's most important discovery based upon his experimental observations was the "Volta pile" (Fig. 20), which consisted of a column of alternating plates of silver and zinc or copper and zinc soldered together on one end and separated by moist cardboard or leather with which he could furnish a constant current of electricity. Volta communicated a description of this "pile" in a letter, "On the electricity excited by the mere contact of conducting substances of different kinds," dated March 20, 1800, addressed to Sir Joseph Banks, the president of the Royal Society in London. In this letter he also described the effects and the construction of the pile as well as his cup apparatus or "couronne des tasses," as he called it, which was very similar to the Volta pile. He described the construction of his battery in the following words:

"I obtain about a dozen little 20 unit plaques of discs of copper, of brass or better of silver; of a thumb's breadth, and an equal number of plaques of tin or, which is much better of zinc, of about the same shape and size. I prepare in the beginning a sufficient number of rounds of cardboard, leather, or some other spongy material capable of absorbing, holding a great deal of water, or of the moisture which is necessary for the success of the experiment.

"I place then horizontally upon a table or other base, one of the metal plates, for example, one of silver, (A = argentum) and on this first I fit a second of zinc (Z = zinc); on the second I lay one of the wet discs; then another silver plate, immediately afterward another zinc one, after that I put in sequence another wet disc. I continue so, in the same manner, coupling a plate of silver with one of zinc, and always in the same order, that is to say, always the silver below and the zinc above, or vice versa, whichever way I have begun, and interposing between each of the couples, a wet disc; I continue, I say, to build, of many of these stories, a tower as high as can stand without toppling.

* Continued from the August, 1933, issue.

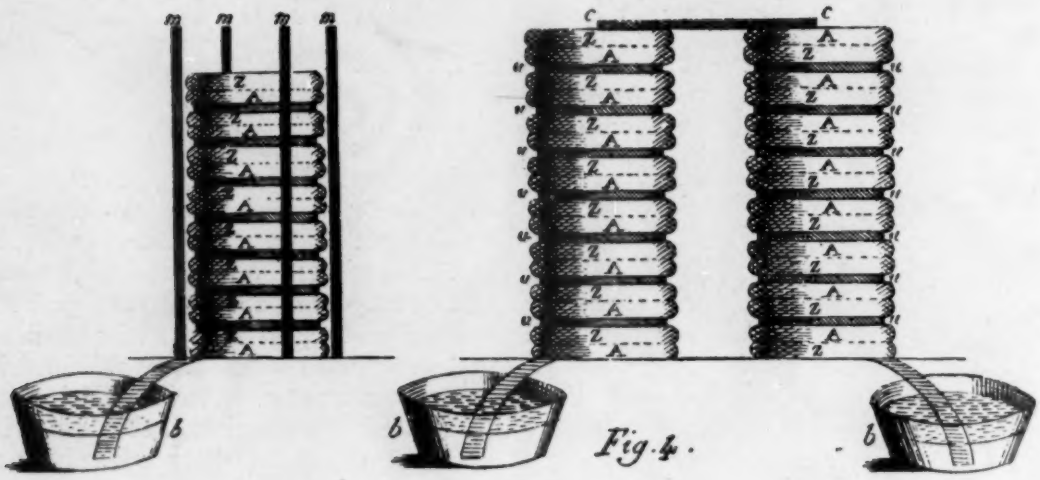


FIG. 20. Volta pile.

"Now, if it will stand up to reach about 20 of these stories of metal couples, it will already be capable, not only of making the electrometer signals of Cavallo, aided by the condenser, to as much as 10 or 15 degrees, of charging the condenser by simple touching to the point at which it will give a spark, etc., but also to shock the fingers with which one tries to touch its two ends, (the head and the foot of one such tower), with one or many little shocks, and more or less frequently, whenever one renews these contacts; every one of which resembles perfectly the slight effect given by a Leyden jar weakly charged, or a battery charged even more weakly, or finally an extremely exhausted torpedo, which imitates even better the effects of my apparatus on account of the shocks which it can give without ceasing."

From these experiments resulted the construction of the voltaic cell which revolutionized the science of physics and chemistry. The enthusiasm with which the Volta pile and the Volta cups were received may well be compared with the feverish activity which followed the discovery of the roentgen rays a hundred years later. In both cases, along with accurate observations of new and fundamental effects which were based upon the discoveries, there were many fanciful reports and wild speculations. One must remember, however, that the production of electricity by means of the Volta pile was so different from that by means of the static machines, that there were serious doubts that both electricities were of the same nature. Another important apparatus built by Volta was the "electrophorus," an instrument with which he studied the distribution of electrostatic charges in an insulator. Professor Wilcke, mentioned previously, also seems to deserve some credit for similar studies. Volta died at the age of eighty-two, highly honored, on March 5, 1827, at his home in Como. In 1878 a monument to him was erected in Como. The original pile made by him and many of his other pieces of apparatus which had opened entirely new fields of science were collected for an exhibit in Como to celebrate the centennial of the discovery of the Volta pile; unfortunately all of this valuable collection was destroyed there in the great fire in 1889.

The fundamental experiments of Galvani and Volta soon led to the construction of new apparatus which were destined to play a most important rôle in the discovery of the roentgen rays. The greatest progress which was brought about by the discovery of the Volta pile took place in the middle of the nineteenth century. It depended upon observations made by Hans Christian Oerstedt (1777–1851) (Fig. 21), a Dane, who conducted most important experi-

ments on the interrelationship of electrical and magnetic phenomena.

Oerstedt was born on August 14, 1777, the son of an apothecary who lived in very modest circumstances in Rudkjöbing on the island of Langeland. In 1799 he obtained his Ph.D. degree after having already won several prizes at the University for his achievements. In 1806 he was appointed Associate Professor and in 1817 full Professor of Physics at the University of Copenhagen. He spent his whole life in Copenhagen, although he made frequent trips to visit his colleagues at most of the universities in Europe. He died, highly honored, at Copenhagen on March 19, 1851.

According to his own statement, Oerstedt suspected as early as 1813 that a certain correlation existed between electric and magnetic phenomena, but his famous discovery of the deviation of a magnetic needle by a conductor through which a current was flowing, was not made until many years later, on July 21, 1820. This discovery ended many a wild fantastic speculation of a number of philosophers who had reasoned for a long time that there must be some association between the Volta pile and the magnet. Oerstedt's discovery was made during a thunder storm when he placed a magnetic needle upon a table to observe its behavior under the influence of the storm. Nothing particularly interesting happened until he suddenly noticed a deviation of the magnetic needle when he accidentally connected the two ends of a Volta pile which happened to stand beside the needle, with a platinum wire. He repeated and investigated this first observation very carefully and found soon that the needle "if placed above or below the wire placed itself at right angles to it, the north pole pointing in one direction when the needle was above, and in the opposite direction when it was below. The direction of the north pole is one way or the other according to the direction that the positive electricity moves in the wire." Oerstedt communicated the results he had

Fig. 21. Hans Christian Oerstedt (1777–1851).

observed on July 21, 1820, to a number of scientific societies and to many of his friends in a letter written in Latin with the title—"Experiments on the Effect of an Electrical Conflict on the Magnetic Needle." This important communication describing the birth of electromagnetism was printed in the *Annals of Philosophy* in the same year.

The sensational discovery of Oerstedt found a brilliant interpreter in the Frenchman, André Marie Ampère (1775–1836) (Fig. 22), who presented his theories on the phenomenon observed by Oerstedt to the French Academy of Science, as early as September 18, 1820, only a short time after he had heard of Oerstedt's experiments. He stated that the Volta pile itself, as well as its outside connection, has an effect upon a magnetic needle, and that this effect proved that an electric current must flow in the pile circuit and must act upon a magnetic needle all along the circuit. He furthermore set up the rule for the direction in which this needle would point, the

FIG. 22. André Marie Ampère (1775–1836).

means of recognizing this direction and the law to determine the direction in which the current deviated the needle. Based upon his own opinion, as well as on important experiments of D. F. J. Arago and H. Davy who had observed that the connecting wire of a voltaic battery could magnetize iron, Ampère showed that electric conductors have a dynamic effect upon each other. He found that conductors in which the current flows in the same direction repel each other and those in which it flows in the opposite direction attract each other and therewith laid the further foundation for electro-dynamics. Ampère made a sharp distinction between electric current and electric tension. He called the measuring apparatus used by du Fay and Nollet and others "potential meters." "In order to measure an electric current," he said, "one must use instruments which measure the strength of the magnetic effect of these currents." He thus made for the first time a sharp distinction between electrostatics and electrodynamics.

Of almost equal importance with Ampère's theories were his experiments determining the magnetic effects of electric currents upon each other. The construction of the solenoids or the "current coil" and the basic principles of electrodynamics depend upon these experiments and they are the foundation upon which a tremendous amount of electrical technique subsequently depended. Ampère, the "father of electrodynamics," was able to arrive at his brilliant results which were "perfect in form and unassailable in accuracy," as Maxwell once said, by his extraordinary mathematical analysis combined with great experimental skill. He picked his way through complicated theories and experiments with a sure-footedness as uncanny as that of a somnambulist.

André Marie Ampère was born on January 29, 1775, in Polemieuz, near Lyon. As a child he already had shown great interest in mathematics and other scientific problems. At the age of twenty-six years he was made Professor of Mathematics in the Lyceum at Lyon. He had obtained this latter position after publishing a little pamphlet in which he showed mathematically that in gambling the chances are always against the professional gambler. also this pamphlet probably was one reason for his being called to the Technical High School in Paris where he was elected Professor of Mathematics in 1809. There he accomplished practically all of his important work on electromagnetism. He died on June 10, 1836, at Marseilles.

Numerous investigators who followed Volta and Ampère made valuable contributions to the knowledge of electricity which cannot be discussed here. The next great strides in advancement were made by G. S. Ohm (1787–1854) a German, and Michael Faraday (1791–1867), an Englishman. George Simon Ohm (Fig. 23) came from Erlangen. His father was a locksmith but he was very much interested in mathematics and natural sciences and influenced his son to learn something of these branches of science. Ohm studied at the University

of Erlangen and obtained his degree after several interruptions. For many years he taught in high schools and finally was made Professor of Mathematics at the Polytechnic School in Nürnberg in 1833. After years of waiting and many petitions to the government, his desire to work at a large university was granted and he was made Professor of Experimental Physics at the University of Munich, in 1852. Unfortunately he did not enjoy his new position very long, for he died two years later, on July 7, 1854. Ohm's most important work was done when he was teaching at the Cologne Jesuit High School about 1825 but was incompletely described in short communications because of lack of time and poor laboratory facilities. It was not until 1827 that a complete and masterful presentation of his results was published in Berlin with the title "The Galvanic Chain Mathematically Considered." Ohm's work was formulated in the law which bears his name—"Ohm's law"—a mathematical formula stating the relationship of current, electromotive force, and resistance. This law states that in an electrical circuit the current is in direct proportion to the electromotive force, and inversely proportional to the resistance. His first experimental tests of the law were made with the current obtained from a Volta pile, but because of the inconstancy of this pile he later employed a thermocouple which had just been discovered by T. F. Seebeck in July, 1821. The correctness of this famous law was subsequently supported by the experiments of many prominent physicists so that the doubts existing when it first became known were soon removed.

Fig. 23. G. S. Ohm (1787–1854).

Fig. 24. Michael Faraday (1791–1867).

Michael Faraday (Fig. 24) who was a contemporary of Ohm, was born on September 22, 1791, in Newington, Surrey, near London, the son of a blacksmith. In his youth he was an errand boy and an apprentice in the establishment of a bookbinder, C. Riebau in London. This occupation gave him plenty of opportunity to read books and a series of letters to his friend, Benjamin Abbot, throw considerable light

upon his self-education and his ideas at that time, when he first became intensely interested in science. In 1812, Mr. Dance, a friend, took young Faraday with him to hear four lectures on chemistry by Sir Humphrey Davy at the Royal Institution. Faraday made copious notes during the lectures and at home worked them out most carefully. When Mr. Dance saw the intense interest which Faraday took in these lectures he told him to write direct to Davy, and Faraday did so, enclosing his notes on Davy's lectures. Much to Faraday's surprise, Davy's reply was "immediate, kind and favorable";

1812
Christmas Eve.

"*Sir*,

I am far from displeased with the proof you have given me of your confidence, and which displays great zeal, power of memory, and attention. I am obliged to go out of town and shall not be settled in town till the end of January; I will then see you at any time you wish. It would gratify me to be of any service to you; I wish it may be in my power.

I am, Sir, your obediant servant

H. DAVY"

On March 8, 1813, Davy took Faraday into the Royal Institute as a laboratory assistant, with a weekly salary of twenty-five shillings and gave him two rooms in the institution. Faraday was able to earn Davy's confidence in a very short time so that after six months he was permitted to accompany him and Lady Davy as a scientific assistant, secretary and servant on a two-year trip through Europe. The party visited many of the famous scientific laboratories, and thus Faraday came in contact with many of the continental scientists. A few years later Faraday became a member of the Royal Society in spite of Davy's objections which were mainly based upon jealousy, or perhaps rather on the jealousy of Lady Davy. In 1820 Faraday gave his first lecture before the Royal Society; in 1829, when Davy died, he was appointed Director of the Laboratories and in 1833 he was made Fullerian Professor of Chemistry at the Royal Institution without being obliged to give lectures. He kept this position for fifty-four years until his death on August 25, 1867, in Hampton Court near Richmond in the house given to him by Queen Victoria.

Faraday was intensely interested in Oerstedt's discovery and Ampère's fundamental deductions from it. In 1821 he repeated all of Oerstedt's experiments and wrote a historical survey of the evolution of electromagnetism up to April, 1821. In repeating the experiments, he made his first important discovery. On Christmas day, 1821, he showed his young wife his famous experiment of a magnetic needle rotating around a wire carrying an electric current. He repeated and enlarged upon the experiments of these scientists; he was especially interested in the correlation between electric and magnetic forces. He reasoned that since a magnet is influenced by an electrical current, a magnetic current must produce electric forces in conducting wires. In the fall of 1831 he made his most fruitful discoveries. On August 29, 1831, he discovered when moving a magnet inside a copper wire coil (or "making" and "breaking" the circuit in the primary of his "classical transformer") that an electrical current was flowing through the coil (Fig. 25). He had early suspected some connection between electricity and magnetism other than that described by Oerstedt and had predicted this important phenomenon which he now called "electromagnetic induction," as early as December, 1824. He commented upon his new discovery in a letter to his friend, R. Phillipps, on September 23, 1831, in the following words: "I am working again on electromagnetic problems, and I think I have something valuable, but I do not want to talk about it yet. Perhaps after all my efforts I will pull weeds instead of fish out of the water." This important principle of electricity, which, together with Oerstedt's discovery, form the basis of modern science, eventually led to the construction of the magneto-electric machine, the induction coil, the transformer, shortly to those apparatus which produce strong electric currents of

high voltage such as were used by Roentgen when he discovered the x-rays.

It is impossible to relate in detail all the brilliant experiments of Faraday which led to his discovery of electro-magnetic induction, or the many and valuable accomplishments that resulted. It must suffice to state briefly that he pointed out magnetic and electric lines of force, described magnetic induction, laid down the law of induction and the principles for production of continuous induction currents from a coil rotating between magnetic poles, the principle of earth induction, self induction, etc. He published a résumé of the knowledge of certain phenomena which had been described by many scientists and he explained how they were produced by electricity, and concluded that all of these phenomena must have come about through the same agency. In a lecture before the Royal Society he expressed this theory in the following words: "I have long held the opinion, almost amounting to conviction, in common, I believe, with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin; in other words, are so directly related and mutually depended, that they are convertible, as it were, to one another, and possess equivalents of power in their action."

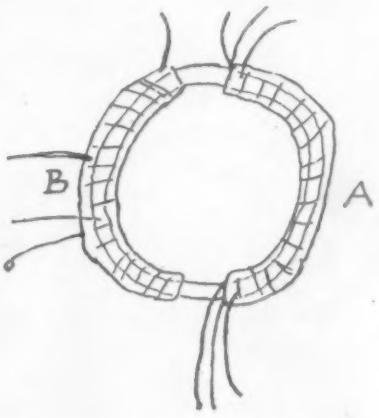


Fig. 25. Faraday's induction ring. A, primary and B, secondary windings (copy of Faraday's original drawing).

Fig. 26. Joseph Henry (1797–1878).

In 1838, Faraday started his investigations on high tension discharges through rarefied gases, which had been neglected ever since Abbé Nollet's experiments. The renewed interest in these experiments was due to the development of a glass vacuum tube which had platinum electrodes fused into the tube. They were the creation of Heinrich Geissler, a young glassblower of Bonn. Faraday studied the peculiar discharges in tubes which contained small amounts of rare earth. His name became associated with the dark space which surrounds the negative electrode, the size of which depends upon many factors, such as vacuum, potential differences at electrodes, etc. He also investigated the question as to whether or not the ether oscillations propagated from the electrode are of a corpuscular nature.

A contemporary of Faraday who made important experiments along the same lines, was the American, Henry. Joseph Henry (Fig. 26) was born in Albany, N. Y., on December 17, 1797, the son of a day

laborer. In his early youth he attended the public school and after school worked as a helper in the village store. He then entered Albany Academy, paying his own expenses from money earned by tutoring. In 1826 he accepted the offer to be Professor of Mathematics and Natural Philosophy at the Albany Academy, and six years later he was offered the Chair of Natural Philosophy at the College of New Jersey (now Princeton). During his professorship at Albany he worked on the principles of electro-magnetic current, and on an electro-magnetic motor. He made an electro-magnet capable of sustaining fifty times its own weight. After the establishment of the Smithsonian Institute in Washington in 1846, Henry was chosen as its first secretary and director. He developed the principle of the first electro-magnetic telegraph and of the dynamo and finally made a thorough study of producing induced currents. Henry's investigations were deepened and widened during his Princeton and Washington years. In 1868 Henry was elected President of the National Academy of Sciences and he held this office until his death. He died in May, 1878, in Washington, highly honored by his country. Henry's delayed publications were responsible for the fact that he does not share equal fame with Faraday, though in some of the important discoveries he undoubtedly takes precedence over Faraday. The Italian priest F. Zantedeschi who made similar experiments at the same time shared this fate with Henry. When Henry heard in 1832 of Faraday's fundamental experiments he wrote the following:

"Before having any knowledge of the method given in Faraday's account, I had succeeded in producing electrical effects in the following manner, which differs from that employed by Mr. Faraday, and which appears to me to develop some new and interesting facts. A piece of copper wire about thirty feet long and covered with elastic varnish, was closely coiled around the middle of the soft iron armature of the galvanic magnet. The armature thus formed with wire was placed in its proper position across the ends of the galvanic magnet, and there fastened so that no motion could take place. The two projecting ends of the helix were dipped into cups of mercury and there connected to a distant galvanometer by means of two copper wires, each about forty feet long. This arrangement being completed, I stationed myself near the galvanometer and directed an assistant at a given word to immerse suddenly in a vessel of dilute acid the galvanic battery attached to the magnet. At the instant of immersion the north end of the needle was deflected 30° to the west, indicating a current of electricity from the helix surrounding the armature."

Some of Faraday's observations on electro-magnetics were enlarged upon by the German, Professor Wilhelm Weber (1804–1890), and by the Roumanian, H. F. E. Lenz (1804–1865), a member of the St. Petersburg Academy of Sciences. Weber determined the absolute measure of electro-magnetic force which was one of the most important consequences of Faraday's work because it furnished the basis for exact quantitative measurement of electro-magnetism. Lenz, after repeating Faraday's principal experiments, elaborated upon them considerably and among other investigations studied quantitatively the relation between electromagnetic induction and the mechanical action of electric currents by means of a sensitive galvanometer.

In this connection mention must be made of the improvements which were made in electrostatic machines or the so-called "influence machines." G. Belli built in 1831 a new machine which had a much greater output than the type constructed by von Guericke in 1663. The first design for an "influence machine" seems to have emanated from the principle of the "electrophorus" and is probably due to Abraham Bennet who already has been mentioned as the inventor of the improved gold leaf electroscope. Other scientists improved upon this design. The more modern type of influence machine used today was introduced during the sixties of the last century, and is based upon the ideas of the Englishman, G. F. Varley and the Germans, Au-

gust Toepler (1836–1912) and W. T. B. Holtz (1836–1913). The apparatus was improved by James Wimshurst whose name is still borne by present machines. Wimshurst's patent of his static machine (Brit. Pat. Spec. No. 206, 1860) remains the foundation for all later constructions. In his machine Wimshurst still used glass plates with tinfoil while Holtz in 1880 changed to hard rubber plates following a suggestion by R. Voss, a Berlin mechanic. It is well known that after the discovery of the roentgen rays these static machines were frequently used to produce the high potential for the x-ray tube.

The construction of the instruments to measure potential and current also underwent considerable improvement. R. Kohlrausch (1809–1858) used a swinging wire suspended on a thin glass thread and studied electrostatic deflections with this instrument. The quadrant electrometer which was a great improvement on this type of instrument was designed by the English physicist, William Thomson (Fig. 27) (1824–1907), who later became Lord Kelvin. Kelvin had made a detailed study of the various types of electrometers in use at this time.

Fig. 27. Lord Kelvin (William Thomson) (1824–1907).

Fig. 28. James Clerk Maxwell (1831–1879).

The electrical foundation for the important investigations to come were thus pretty well developed. Faraday's work had given the basis for the construction of high tension transformers; electrostatic machines for the same purpose were developed. The progress made at that time in the construction of vacuum tubes should also be noted. It was through Faraday's experiments that a new interest was awakened in the study of electrical discharges from evacuated tubes. In 1843, a Frenchman, Abria, observed the striated effect in vacuum tubes and studied the influence of polarity. Grove, Quet and Sequin continued the investigations in the following years (1852–1858), and another Frenchman, J. P. Gassiot, contributed many important observations on evacuated tubes. He found that the potential from a battery of over 3,500 cells

would produce the same phenomenon in an evacuated tube as that created by an induction coil.

These coils were built upon the electro-induction principle. The first induction coils were built by W. Sturgeon, in 1836, and by C. G. Page, in 1838. C. E. Neeff, J. P. Wagner and J. W. Gauley improved the apparatus by adding the mechanical interrupter and in 1853, H. L. Fizeau added a condenser. The best induction coils of that time were constructed by the Parisian mechanic, H. D. Ruhmkorff, and most of the coils constructed afterwards carried his name.

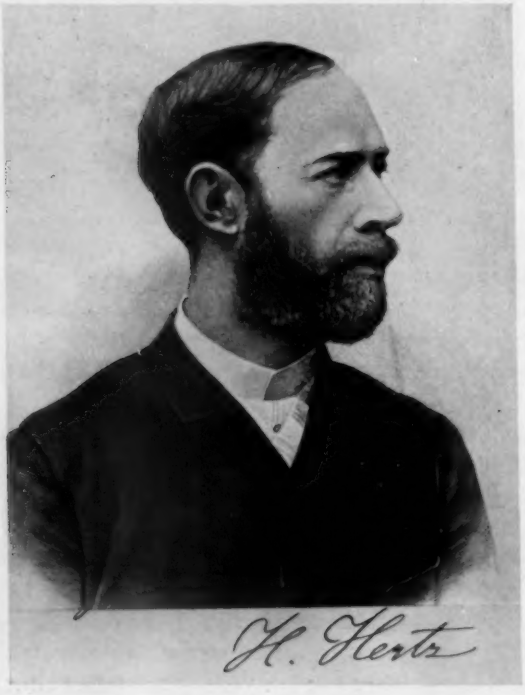


FIG. 29. Heinrich Rudolf Hertz (1857–1894).

The study of electric discharges was retarded because of inefficient methods in the production of vacuum tubes, until 1865 when Herman Sprengel developed the mercury air pump with which a relatively high vacuum could be produced very rapidly, and thereafter better tubes resulted.

In addition to these technical inferences drawn from Faraday's brilliant experiments, the important theoretical conclusions made by James Clerk Maxwell (1831–1879), a Scotchman, Professor of Experimental Physics in the University of Cambridge, must be mentioned. Maxwell (Fig. 28) who was graduated at Cambridge in 1854 when Faraday was sixty-three years old, became deeply interested in the theoretical significance of Faraday's observation of electrical and magnetic fluxes and successfully translated Faraday's work into the language of mathematics. He reported his work in the book "A Dynamical Theory of the Electromagnetic Field" (1863), but his greatest work, the well-known Maxwell differential equations of the electromagnetic field, was first communicated in another paper called, "A Treatise on Electricity and Magnetism" (1873). This work was based on Faraday's conception that electrical and magnetic actions are due to a certain state of the medium between the bodies. Maxwell's further development of this idea finally led to the electromagnetic theory of light. He contended that any change of an electric field results in an electric current with which magnetic effects are associated. Furthermore he deducted that regular oscillations of electric state travel from any source of rapid and regular changes of electric discharge with the velocity of light and with the same frequency. Maxwell's creative theory and his prediction of these propagated alternations were not experimentally substantiated until after his death twenty years later by the experiments of Heinrich Hertz, a German physicist. Maxwell died at the early age of forty-eight, on November 5, 1879.

Hertz constructed a receiving resonator with which he was able to detect oscillations from a specially constructed spark gap—the Hertzian oscillator—through the air anywhere in his laboratory. He saw that the receiving oscillator had the same frequency as that of the sender. He showed furthermore that these electric waves could be reflected on a denser material than air, thus furnishing more proof of Maxwell's theories of the propagation of electrical

and magnetic fluxes. Hertz performed these important experiments on electrical oscillations at the Karlsruhe Technical High School between 1885 and 1889.

Heinrich Rudolf Hertz (Fig. 29) was born on February 22, 1857, at Hamburg. He first studied technical sciences and then physics under C. R. Kirchhoff and H. von Helmholtz, in Munich, Berlin and Bonn, and went to Kiel in 1883. He taught physics at the Technical High School in Karlsruhe from 1885 to 1889 and returned to Bonn in 1889 as the successor of Clausius. Here he was principally occupied with investigations of the electric discharge from evacuated tubes. He died from sepsis at the early age of thirty-seven, on January 1, 1894. He was one of the most brilliant physicists that ever lived. A few days before his death he wrote to his parents: "If something should really happen to me, you should not be sad, but just a little bit proud, and feel that I belong to the selected few who have lived a short life but a full one." Hertz crowded many tremendously important achievements into his few years of life and he laid a most important foundation for subsequent progress in our knowledge of natural sciences. Perhaps the value of his work was characterized best by his famous teacher, von Helmholtz, in answering a letter of inquiry from the University of Bonn when this university sought a successor for Hertz. He wrote, "In looking for a successor for Hertz, it seems quite impossible to find somebody who is able to replace this unique man."

Fig. 30. H. Geissler (1815–1879).

Fig. 31. Julius Plücker (1801–1868).

The researches of Hertz on the electric discharge in rarefied gases continued the experiments of his predecessors and were made possible by the development of the Geissler tubes. H. Geissler (1815–1879) (Fig. 30) was a modest glassblower at the University of Bonn who was given the honorary degree of Ph. D. in 1868 by the University of Bonn in recognition of his valuable assistance in many physical researches. Among other things he found that when his tubes were filled with different gases at a pressure of one to two

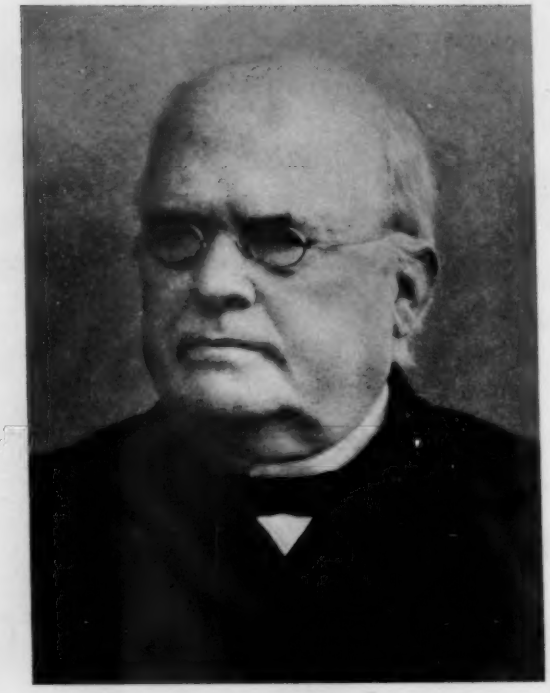


FIG. 32. Wilhelm Hittorf (1824–1914).

millimeters of mercury they displayed wonderful color effects. Julius Plücker (1801–1868) (Fig. 31) the Professor of Mathematics and Physics, at the University of Bonn, gave Geissler great encouragement in his work. Plücker was more a theorist than an experimental physicist and needed skillful collaborators to carry out his ideas. Plücker and Geissler investigated the spectrum obtained from various gases enclosed in the Geissler tubes. Plücker was the first to observe the green glass fluorescence in the tubes opposite one of the electrodes and together with his student, Hittorf, he studied the influence of a magnet upon the radiations emanating from the cathode.

Wilhelm Hittorf (1824–1914) (Fig. 32) came from the family of a merchant in Bonn and obtained his Ph.D. at the age of twenty-eight, at the University of Bonn. A year later he was made "Privatdozent" at the University of Bonn but soon went to the Academy of Münster as Dozent for Physics and Chemistry. Conditions at this Academy at that time were rather bad and he was furnished with only a small auditorium and a meagerly equipped laboratory which was not heated. His budget was 50 taler a year and his yearly salary was 300 taler. In spite of these adverse conditions, Hittorf began his researches, gave many lectures, and gradually enlarged his laboratory. He was appointed Associate Professor in 1852 with a salary of 450 taler, and in 1856, he was made full Professor of Physics and Chemistry after he had declined to accept the Chair of Physics at the University of Bern. At the time of his death at Münster, on November 28, 1914, he was ninety years old and had been Professor Emeritus at the University for twenty-five years.

The value of Hittorf's accomplishments was not immediately recognized. He was one of the first to clarify some of the unknown and mysterious effects observed on the discharges of electricity through rarefied gases which had been previously noted by Abbé Nollet, Hauksbee and subsequently by many others. In his investigation of this subject Hittorf made tubes

FIG. 33. William Crookes (1832–1919).

having a much higher vacuum than those made by Geissler. He had to overcome many difficulties in making these tubes. He had only a Geissler pump in his institute and it required much strenuous manual labor to lift a vessel full of mercury; it took several days to obtain a satisfactory vacuum. One of Hittorf's most important observations was that the light from the negative electrode (the cathode) of the vacuum tube leaves the electrode in straight lines, produces heat and causes fluorescence on the glass where it impinges. In 1869 he discovered that when solid matter is brought into the path of this light, a shadow of it is cast upon the glass walls of the tube. Plücker later found that this light could be deflected by a magnet. "The light ray acts as an unending, thin, straight, weightless, stiff current string, which remains attached when its one end touches the negative section." Hittorf's important observations on these cathode rays were described in four publications in the years 1869 to 1884 and created a great sensation. Varley, who has been mentioned previously, advanced the hypothesis that negatively electrified particles are shot out from the cathode and can be deflected from their straight path by a magnetic field. The English physicist, William Crookes (1832–1919) (Fig. 33), substituted and enlarged upon these theories, but he was of the opinion that the radiation emanating from the cathode represented a fourth state of matter, so-called "radiant matter." It remained for Crookes to show, by a series of very careful and brilliant experiments, that matter was actually emitted from the cathode, and possessed enough energy to rotate a small wheel which he placed within the tube. Crookes demonstrated his experiments to the members of the Royal Institute on August 22, 1879, in a brilliant lecture which has become classic.

W. Crookes, who was the son of a tailor, was born in London on June 17, 1832. He studied chemistry at the Royal College of Chemistry under von Hofmann. In 1851, von Hofmann made him his assistant and in 1855 he accepted a position as chemist in a laboratory in Chester where he worked on the spectra of various substances and discovered the green line of a new element, thallium. He investigated the properties of thallium very carefully and when attempting to determine its atomic weight in vacuum he designed his "radiometer" which in turn in its further development paved the way to his famous experiments on "radiant matter." After 1856 he lived in London where he had a private laboratory in his home. In later years he devoted most of his time to chemical and physico-chemical problems. He was highly honored and was knighted in 1897. From 1913 to 1915 he was President of the Royal Society. He died April 14, 1919, in London.

Crookes' most important studies were those on the electrical discharges through rarefied gases. In contrast to Hittorf, who published his results with great modesty in somewhat inaccessible journals, and whose books were very technical and dry, Crookes was a brilliant writer, demonstrator and lecturer. He was very successful in conveying his information about the cathode rays to a great many scientists. Therefore, he was given credit often for observations that had really been made years before by Hittorf. The tubes with which x-rays were subsequently discovered were usually called Crookes tubes instead of Hittorf tubes, both before and after the discovery of the rays. "Crookes dark room" also designated a phenomenon which had been described by Hittorf many years before. The few voices calling attention to the credit which was due Hittorf in many of these investigations received little consideration. For instance, the Director of the Royal Observatory at Berlin published the following note in the "Reichsanzeiger" in 1896:

"The lively interest created through the discoveries of Professor Roentgen permits us to correct a few misunderstandings which had been given in the news of this discovery and its historical background. Some of the terms used at the present time, such as Crookes rays, Crookes tubes, etc., should not be used. Most

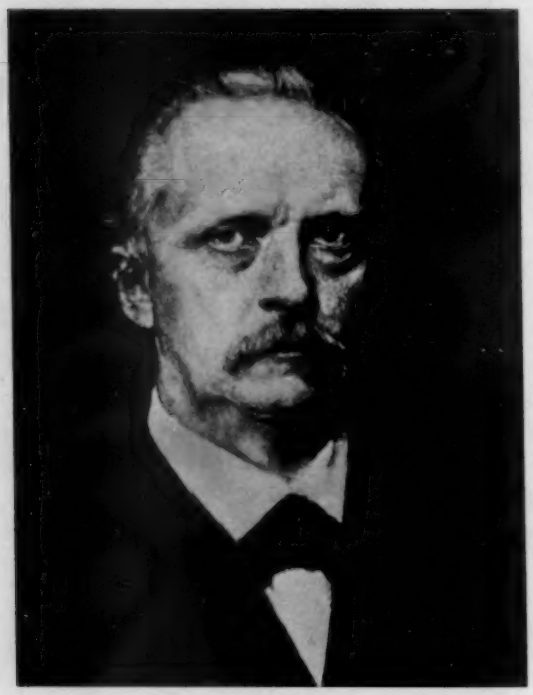


Fig. 34. H. von Helmholtz (1821–1894).

of the experiments published by the English physicist, Crookes, on the so-called cathode rays were carried out many years ago by Hittorf in Muenster and by Goldstein in Berlin. Crookes added only a few insignificant details and he acknowledged the priority of the German workers in the 'Chemical News' of May 30, 1879. However, in his famous lecture which was given before the British Association in August, 1879, he omitted to mention this fact again. The German translator of the latter publication did the same thing, and, therefore, an incorrect tradition of the work has been propagated." (*München. med. Wchnschr.*, 1869, *43*, 68.)

Also in England a few scientists called attention to the priority of Hittorf in many of these experiments. (*Brit. J. Photography*, 1896, *43*, 111.)

The fundamental researches of Hittorf and Crookes on the radiation emanating from the cathode and the theories of von Helmholtz were responsible for the success of Hertz's experiments. In *Wiedemann's Annalen*, Vol. 48, von Helmholtz (Fig. 34) had presented his theory of electro-magnetic dispersion which was based on Maxwell's equations, predicting the existence of electro-magnetic oscillations of very high frequencies. Von Helmholtz was able to foretell certain properties of the hitherto unknown radiation which later was discovered to be the x-ray. For example, he described the phenomena of deflection, diffraction, and penetration. The Helmholtz theory could also be applied to rays of smaller frequencies and at the time it became known was well substantiated by Hertz's brilliant experiments. Von Helmholtz really predicted theoretically Roentgen's great experimental discovery.

Hertz's important work was continued by his pupil, Philipp Lenard (Fig. 35). Lenard was born on June 7, 1862, in Pressburg, Hungary, a son of the merchant Philipp von Lenard. He studied mathematics and natural sciences in Budapest, Vienna, and Heidelberg, under von Helmholtz, Bunsen and Quincke. In 1886 he obtained his Ph. D. degree and became an assistant to Quincke in Heidelberg. In 1891

Fig. 35. Philipp Lenard (1862–).

Hertz asked him to come to Bonn as Privatdozent. After the death of his teacher, Lenard went to Breslau and then in 1895 to Aachen where he was made Dozent of Theoretical Physics. A year later he accepted the call to the Chair of Physics at the University of Heidelberg where he was also made Director of the Physical Laboratory of the University. Lenard deserves much credit for the important investigations of the property of cathode rays which made him the immediate predecessor of Roentgen. In 1892, Hertz had demonstrated (experimentally) the transmission of cathode rays through metals. He pasted thin gold, silver or aluminum foil upon the inside of a uranium glass disc and found that a fluorescence of the glass could be observed even after the cathode rays had passed through the metal foils. Lenard, discussing these fundamental experiments in his Nobel lecture said,

"One day Hertz called me into his office, an event which, much to my regret, took place very seldom, and showed me an observation which he had just made. A piece of uranium glass inside an evacuated tube was covered with aluminum foil and showed fluorescence under the foil. He told me one could separate two spaces by aluminum foil, and also asked me to continue the experiments, which he did not have time enough to do. In one space the rays could be produced as usual, but in the other space they could be observed in a purer state than ever before. However, on account of the thinness of the foil there should only be a small difference of air pressure between the two spaces. Still one of the two spaces could be well evacuated, and one could study whether or not this would affect the production of the cathode rays, that is, one could see whether or not they were phenomena produced in matter or processes within the ether."

Lenard continued Hertz's experiments by placing a thin aluminum foil (0.0026 mm. in thickness) window opposite the cathode in an evacuated tube. With a few particles of fluorescent potassium phosphate he could see that the cathode rays not only penetrated through the window but also travelled quite a distance in the free air. This important observation was made for the first time on October 20, 1892. Hertz realized the great significance of this observation at once and expressed his opinion to von Helmholtz in a letter dated December 15, 1892:

"A very peculiar discovery was made in the last weeks by Dr. Lenard, my assistant. He closed Geissler tubes with extremely thin aluminum foil and succeeded in using foil of proper thickness to keep the vacuum but still permit an appreciable amount of the cathode rays to go through them. He has found that these rays after once being produced can be propagated through air and through various gases; this opens an entirely new field of investigation because it is now possible to completely separate the production of these rays from their observation. I advised Dr. Lenard to send a short communication to the Berlin Academy on account of the importance of his results."

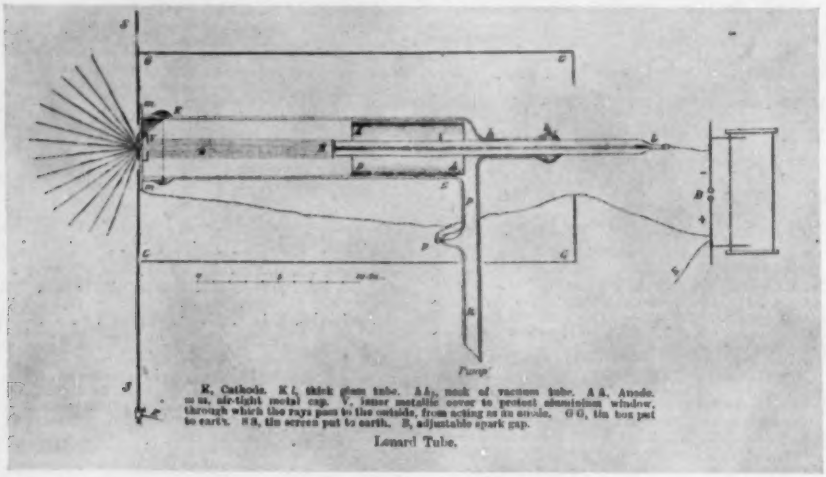
The outstanding investigations by Lenard which followed upon this first discovery are well known. They provided a significant basis for the important discovery of the roentgen rays, a fact which Roentgen mentioned in his first communication by speaking of Lenard's "wonderful experiments."

Lenard noted that cathode rays are not visible but their effects can be studied with fluorescing substances such as phosphates and ketones. Apparently he did not use barium platinum cyanide at that time. He also found that the cathode radiation darkens photographic plates, an observation which had been made also by the Berlin physicist, Goldstein, in experiments in which the plate was brought inside the tube.

Lenard's cathode-ray tube (Fig. 36) with which he made his important observations, is well known. Such tubes were also among those used by Roentgen at the time of the discovery of the roentgen rays and one of them is still to be seen in the Museum of the Würzburg Physical Institute. Lenard later improved his first tubes by sealing a thin aluminum window upon a platinum cylinder which was fused into the glass.

With a fluorescent screen, Lenard showed that the air near the window of the tube acted like a cloudy medium. The rays which were propagated in straight lines within the tube were scattered in all directions outside the window; from this he reasoned that the molecules of air scattered the rays, probably just as ordinary light is scattered by fat globules in milk. He concluded that the rays must be something extraordinarily fine, and therefore he started to investigate photographically their penetration through solid matter. He found that the density of the absorbing material is important, but not its physical state. Gold showed the greatest absorption of the cathode rays, silver somewhat less, and aluminum still less. If equal thicknesses (0.000071 mm.) of the metals were used and if metal parts of the same weight per area (0.75 mg. per sq. mm.) were used, equal absorption was observed. In these experiments Lenard employed his familiar aluminum "ladder" which had from one to nine layers of aluminum foil, 0.0014 mm. thick, and was used successfully to analyze the penetration of various cathode-ray beams. Such metal ladders were frequently employed for absorption measurements of x-rays after Roentgen's discovery.

Lenard's experiments led him to study the laws of mass proportion of the absorption of cathode rays and then to question whether the phenomena observed with the cathode rays were taking place in matter or in ether. He concluded that ether was concerned although he did not believe in ether waves. He advocated this theory against that of the English school, whose protagonists believed in a "stream of electric particles" or "electrolytic radiation." Lenard attempted to support his theory experimentally by passing the cathode rays from one tube into another which was highly evacuated, so that the sharply defined cathode beams in this second tube could be deflected by a magnet and thus studied to better advantage than when the cathode rays were scattered in air.



Lenard Tube.

FIG. 36. Lenard's tube.

Lenard also replaced the aluminum window in his tube with a thin glass window and obtained equally satisfactory results but he personally preferred the aluminum window on account of its lightness and ease of manipulation. He also made the important observation that there were different kinds of cathode rays which were deflected to a greater or less degree by means of a magnet. This fact had also been noted by Goldstein who was the first to observe the positive channel rays and who described fluorescence in the glass wall and

also observed the phenomenon of scattering of the cathode rays. His observations that cathode rays discharge electrically charged bodies, independent of their charge, was of great importance.

Lenard's investigations, as well as all the brilliant work done by the many other investigators of cathode rays (Elster and Geitel, Goldstein, Puluj, Lehmann, Schuster, E. Wiedemann, Warren de la Rue, W. Spottiswood, J. J. Thompson, J. Perrin, L. Weber, A. A. de la Rive) cannot be detailed at this time.

This, then, was the state of affairs in the construction of high tension apparatus and concerning the knowledge of discharges of electricity through rarefied gases when Wilhelm Conrad Roentgen started to make practical experiments on these problems in October, 1895. Soon thereafter he dis-

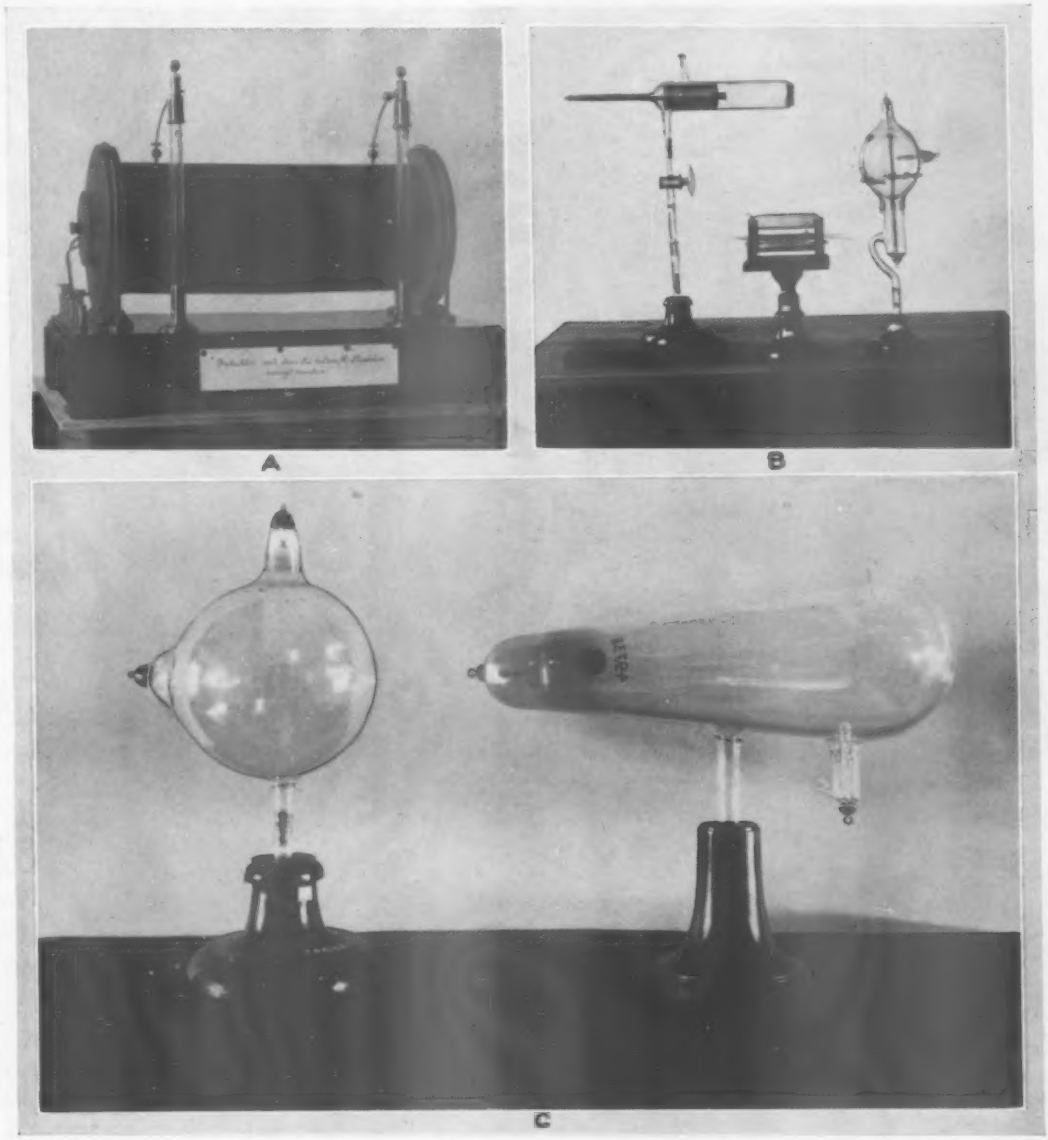


Fig. 37. Roentgen's original apparatus with which he discovered the x-rays. A. Ruhmkorff induction coil. B. Lenard tubes. C. Hittorf-Crookes tubes.

FIG. 38. Roentgen's first x-ray picture of a hand.

covered the x-rays (Fig. 37). One of the best accounts of this fundamental discovery was given by the English scientist, Sylvanus P. Thompson at a meeting of the newly founded British Roentgen Society on November 5, 1897:

"November the eighth, 1895, will ever be memorable in the history of Science. On that day a light which, so far as human observation goes, never was on land or sea, was first observed. The observer, Professor Wilhelm Conrad Röentgen. The place, the Institute of Physics in the University of Würzburg in Bavaria. What he saw with his own eye, a faint flickering greenish illumination upon a bit of cardboard, painted over with a fluorescent chemical preparation. Upon the faintly luminous surface a line of dark shadow. All this in a carefully darkened room, from which every known kind of ray had been scrupulously excluded. In that room a Crookes's tube, stimulated internally by sparks from an induction coil, but carefully covered by a shield of black cardboard, impervious to every known kind of light, even the most intense. Yet in the darkness, expressly arranged so as to allow the eye to watch for luminous phenomena, nothing visible until the hitherto unrecognized rays, emanating from the Crookes's tube and penetrating the cardboard shield, fall upon the luminescent screen, thus revealing their existence and making darkness visible. From seeing the illumination by the invisible rays of a fluorescent screen, and the line of shadow across it, the work of tracing back that shadow to the object which caused it, and of verifying the source of the rays to be the Crookes's tube, was to the practised investigator but the work of a few minutes. The invisible rays—for they were invisible save when they fell upon the chemically painted screen—were found to have a penetrative power hitherto unimagined. They penetrated cardboard, wood and cloth with ease. They would even go through a thick plank, or a book of 2000 pages, lighting up the screen placed on the other side. But metals such as copper, iron, lead, silver and gold were less penetrable, the densest of them being practically opaque. Strangest of all, while flesh was very transparent, bones were fairly opaque. And so the

FIG. 39. Dr. W. C. Roentgen.
(Photograph made in 1894)

discoverer, interposing his hand [Fig. 38] between the source of the rays and his bit of luminescent cardboard, *saw* the bones of his living hand projected in silhouette upon the screen. The great discovery was made."

The sensational reception of this discovery throughout the civilized world is well known. It has been dealt with in detail in my book "Wilhelm Conrad Röntgen and the History of the Röntgen Rays" (Springer, Berlin, 1931. English edition, Bale, London, 1933.)

Wilhelm Conrad Röntgen (Fig. 39) was born on March 27, 1845, in Lennep, Germany, the only son of a manufacturer and cloth merchant. He studied engineering and physics in Utrecht and Zürich and was made Privatdozent of Physics at the University of Strassburg in 1875. In 1879 he was called to the Chair of Physics at the University of Giessen and in 1888 to the University of Würzburg. It was in Würzburg that he made the discovery of the x-rays in November, 1895. In April, 1900, he accepted the call of the University of Munich and moved to the Bavarian capital by special request of the Bavarian government. In 1901 he was awarded the first Nobel prize for physics. He died, highly honored, in Munich, on February 20, 1923, at the age of seventy-eight.

Roentgen's discovery of the x-rays forms the brilliant climax to the studious application and previous accomplishments of many other scientists: Lenard, von Helmholtz, Hertz, Hittorf, Crookes, and before them, Maxwell, Faraday, Ohm and Ampère, and then Galvani, Volta and Franklin, Henry, and many others, back to von Guericke and Gilbert. They all contributed to the knowledge of the fundamental facts of electricity through the brilliant development of the production of high tension currents and the creation of highly evacuated tubes and the study of the electrical discharges through the vacuum which finally led to the important discovery of the roentgen rays.

Figures 5, 9, 12, 16, 19, 21, 22, 23, 24, 28, and 33, were drawn from old prints by Miss Mary Isom.

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A BASIS FOR THE COMPARISON OF ROENTGEN RAYS GENERATED BY VOLTAGES OF DIFFERENT WAVE FORM

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ABSTRACT

Earlier studies of the relationship between the applied voltage and the emission of general roentgen radiation for various voltage wave forms (*Bur. Standards J. Research*, 1932, 9, 769 (R.P. 505)) have been extended to include generators not previously available. The roentgen-ray output per effective (r.m.s.) milliampere of tube current is found for full wave and constant potential to be nearly the same at any given value of the effective (r.m.s.) voltage. For half-wave generators it is necessary to make allowance for suppressed half-cycle which is useless in the production of roentgen rays but which enters in the measurement of current or voltage with an a.c. meter. Current and voltage measurements with half-wave rectifiers are corrected so as to apply only during the useful portion of the cycle by the application of a factor of $\sqrt{\frac{1}{2}}$ and $\sqrt{2}$ to the corresponding values measured over a whole cycle. The half-wave generator then yields results similar to the other generators. The roentgen-ray quality, as expressed by a full absorption curve, is found to be the same for all wave forms having the same effective (r.m.s.) value, and regardless of peak values. It is thus possible to adequately express the quality of any radiation in terms of the effective voltage used to excite it. This in turn relates the quality directly to that produced by constant potential. Thus the difficulty in the use of a full absorption curve to express roentgen-ray quality—namely, its inexpressibility as a single numerical magnitude—is overcome. All output measurements made in terms of peak voltage and average current are found to be without real significance in quality determinations.

I. INTRODUCTION

ROENTGEN radiation is necessarily and adequately specified physically by its intensity (quantity) and spectral distribution (quality, hardness).

The intensity is defined as the quantity of energy flowing through unit cross section of the beam in unit time. The spectral distribution is defined as the fractional part of the intensity comprised within a uniform narrow wave length (or frequency) interval throughout the roentgen-ray spectrum.

Intensity is ideally measured in ergs per square centimeter per second. In practice, however, intensity is commonly expressed in roentgens per unit time, which are proportional to the electrical conductivity which the roentgen-ray beam imparts to a cubic centimeter of air. This conductivity is, for any given wave length or any given spectral distribution, very closely proportional to the intensity.[1] Since, however, the factor of proportionality varies with the wave length, the ionization chamber indications do not serve to give the relative intensities of different spectral distributions. The conductivity imparted to air by radiations having different spectral distribution is probably a better measure than intensity of their relative therapeutic value; hence, the conductivity of air, expressed in roentgens per unit time, has been internationally adopted as the physical unit of measure of a roentgen-ray dose. But, even in dosage, it is important to realize that the same number of roentgens represents the same dose only when the effective spectral distribution of the radiations is the same.

The spectral distribution of intensity is represented by a curve, throughout the spectrum, plotted as a function of the wave length or the frequency. Its direct determination is cumbersome and subject to considerable error. In practice it is inferred

[1] Deviation from this proportionality occurs only for roentgen-ray beams of such great intensity that columnar ionization takes place. This is seldom encountered in practice.

as quality (or "hardness") from the thickness of an absorber, say copper, required to reduce the number of roentgens in the radiation to one-half. This thickness is called the half-value layer.[2] More complete information of the spectral distribution is inferred from the complete absorption curve[3] obtained with a series of thicknesses of the absorbing material.[4,5,6] In fact, Silberstein[7] has shown that the complete effective spectral distribution curve neglecting characteristic lines is obtainable from an exact absorption curve.

It is well known that the half-value layer falls short of satisfactorily expressing the quality of the radiation; and the complete absorption curve, though adequate, lacks the very desirable simplicity of being expressible as a numerical magnitude. The experimental results published in previous papers[8,9,10] and those to be presented here show, however, that the radiation emitted by a given tube supplied by a generator of any voltage wave form has a quality (full absorption curve) nearly identical with that which could be obtained with some constant potential generator operating at a particular voltage. Furthermore, it is found that with different generators operating to give the same quality, the intensity is more nearly proportional to the effective tube current than to the average tube current.

A roentgen-ray tube, on a given constant voltage, emits a radiation of definite spectral distribution which is independent of the tube current; as the current increases, the radiation increases alike for all wave lengths. The ionization chamber measures the number of roentgens per unit time which, in this case, are proportional to the intensity. As the applied voltage is increased, a larger fraction of the intensity of the roentgen-ray beam falls in the higher frequency—shorter wave length—intervals. The intensity has increased more than the number of roentgens per unit time as measured by the ionization chamber; and the number of roentgens measured has increased more than the dosage of the radiation. Similarly, when a pulsating voltage wave form is used to excite the tube, the quality of the radiation fluctuates during the cycle from the softer initial value of the harder crest value during the wave period; and adds up to some average spectral distribution which the operator seeks to characterize in some definite and simple way. Experiment shows this composite spectral distribution, for the common types of roentgen-ray generator, to be equivalent to that produced by the particular constant potential which produces a radiation having also the same absorption curve. Comparing mechanical rectifiers (full wave) with a constant potential excitation, 150 kv. constant potential caused a radiation having the same absorption curve as produced by 190 kv. (peak) and by 200 kv. (peak) respectively, on two mechanical rectifiers; and this similarity extends over widely different values of the peak voltages. It was also found that these two mechanical rectifiers were, in fact, operated at 150 kv. effective (r.m.s.).[11] Furthermore, for any other given value of the effective voltage, the absorption curves for all three generators were found closely alike for filtrations up to 1.2 mm. of copper.

In addition, for the same effective voltage, the intensity of the radiation, as measured by air ionization, per effective milliampere of tube current was practically the same for the different types of generator, even when the load distorted the voltage wave form. Having established by the resultant absorption curve that the quality

[2] Taylor, L. S. *Bur. Standards J. Research*, 1930, *5*, 517 (R.P. 212).

[3] This is commonly given by plotting the logarithm of the per cent of radiation transmitted, as indicated by the ionization chamber, against the thickness of the absorbing medium.

[4] Pohle, E. A., and Wright, C. S. Limit exposure in radiography; supplementary report. *Radiology*, 1930, *14*, 17–23.

[5] Taylor, L. S. Absorption measurements of x-ray general radiation. *Radiology*, 1931, *16*, 302–321.

[6] Wilsey, R. B. On specification of x-ray quality. *Radiology*, 1931, *17*, 700–713.

[7] Silberstein, L. Phil. Mag. Ser. 7, 1933, *15*, 375.

[8] Taylor, L. S., and Tucker, K. L. *Bur. Standards J. Research*, 1932, 2, 333 (R.P. 475).

[9] Taylor, L. S., Singer, G., and Stoneburner, C. F. *Bur. Standards J. Research*, 1932, 2, 561 (R.P. 491).

[10] Taylor, L. S. *Strahlentherapie* (in press).

[11] See footnote No. 9.

of the radiation from different types of generator is the same when the effective voltage is the same, it is sufficient, for comparing heterogeneous roentgen-ray beams or roentgen-ray generators to measure the radiation intensity at one filtration only and at different effective voltages. That is, two generators yielding the same output per milliampere, at a given filtration and given effective voltage, will function closely alike at other effective voltages and filtrations. This was found to hold with the types of generators used, for filtrations ranging from 0.1 to 1.2 mm. copper. It should be added that, for the same effective voltage, the output per effective milliampere of the tube is alike not only as regards air ionization and absorption curve, but also was found alike as regards percentage depth intensity in media of low atomic number.

The need felt for specifying the quality of the radiation by a single magnitude is thus satisfied by stating the constant voltage which will produce it; and, in addition, the intensity of the radiation having that quality is given as more nearly proportional to the effective than to the average tube current. In fact, it was found that the output per average milliampere varied with peak voltage to such an extent as to be without real significance in most cases. This fact is undoubtedly responsible, in a large measure, for the very great discrepancies between comparisons of roentgen-ray tubes and generators by various observers, many of whom have been prone to compare generators or tubes under widely different load conditions, then correcting the voarius outputs on the assumption that there is a linear relationship between roentgen-ray output and average tube current. For the usual roentgen-ray transformer having characteristically large electrical regulation, this assumption is far from correct.

Another common error has been introduced by improper control of such factors as the capacitance of the aerial system, diaphragming of the roentgen-ray beam, and the type of tube inclosure. Tests made in connection with this and past studies have shown that a variation of any one of these factors influences the final result and it is thus essential that all such factors remain constant throughout any adequate comparison of roentgen-ray tubes or generators.[12]

As a continuation of the study outlined in the foregoing paragraphs, the main objects of the present paper are:

(1) To compare the radiation from a single roentgen-ray tube operated on several types of voltage wave form;

(2) To compare the effect of different criteria of control of applied voltage and tube current;

(3) To show how various radiations may be equated to constant potential radiation.

II. EXPERIMENTAL PROCEDURE

The following types of high voltage roentgen-ray generator were employed: A double disc mechanical rectifier, *B*,[13] having a divided high tension transformer (two transformers in a single tank) and rectifying over approximately 20 degrees of the half cycle; a commercial "constant potential" generator, *C*, having a ripplage[14] of about 2 per cent per milliampere; a "constant potential" generator, *F*, (B.S. Standard) having a ripplage of about 0.2 per cent per milliampere; a half-wave kenotron rectifier, *D*, using the same two-pole high tension transformer previously used for generator, *A;* a full-wave kenotron rectifier, *E;* and a half-wave kenotron rectifier, *G;* using the same high tension transformer as generator *E*.

A single type of thin-walled cerium glass

[12] See footnote No. 8.

[13] The letter designations of generators *A*, *B*, and *C* correspond to those used in earlier publications involving the same generators under the same condition of aerial, tube enclosure, etc. Hence the results given here are for the most part directly comparable with those given in the papers cited earlier.

[14] Up to the present the term "constant potential" has been used in describing the potential supplied by kenotron or other valve tube rectification in which there is, of course, a slight ripple. A more accurate designation of voltages not actually constant but fluctuating about some mean value is "ripple voltage." Thus by a "ripple quantity" (potential or current) is meant a periodic quantity $y=V_0+V_1 \sin(\omega x+\alpha_1)+V_2 \sin(2\omega x+\alpha_2)+\cdots$ in which the constant term V_0 is so large that all values of the quantity are positive (or negative). The amount of ripple ("ripplage" or "ripplance") in a ripple quantity is the ratio to the average value of the difference between the maximum and minimum values of the quantity.

Coolidge tube was used throughout this study.

All generators were so arranged that they could be connected to the same aerial system leading to the roentgen-ray tube (Fig. 1). An interchange of generators could be accomplished in a minute's time so as to eliminate any short-time changes that might occur in the tube. Numerous check runs made at intervals over several months showed no change in the roentgen-ray tube used. An air blast from a high pressure blower was directed against the tube walls for cooling. Half-megohm surge resistors were used at all times in each side of the high tension line for suppressing any surges or high frequency oscillations.

Average and effective (r.m.s.) tube currents were measured in the manner previously described.[15] For the effective current measurements a thermo-milliameter, *B*, was used. To protect the heating element from damage due to surges it was connected into the circuit through 1/32 amp. Littel fuses. In addition, the meter and fuses were short-circuited when not actually being read.

Average and effective (r.m.s.) tube voltages were measured respectively with d.c. and a.c. voltmeters used in conjunction with a 150-megohm non-inductive shielded resistor, *R*,[16] placed across the high tension leads to the tube. The meters were connected in the center of the resistance so as to be near ground potential. This voltage measuring unit never drew more than 1 milliampere from the circuit and hence had no undesirable effect on the operation of the generators.

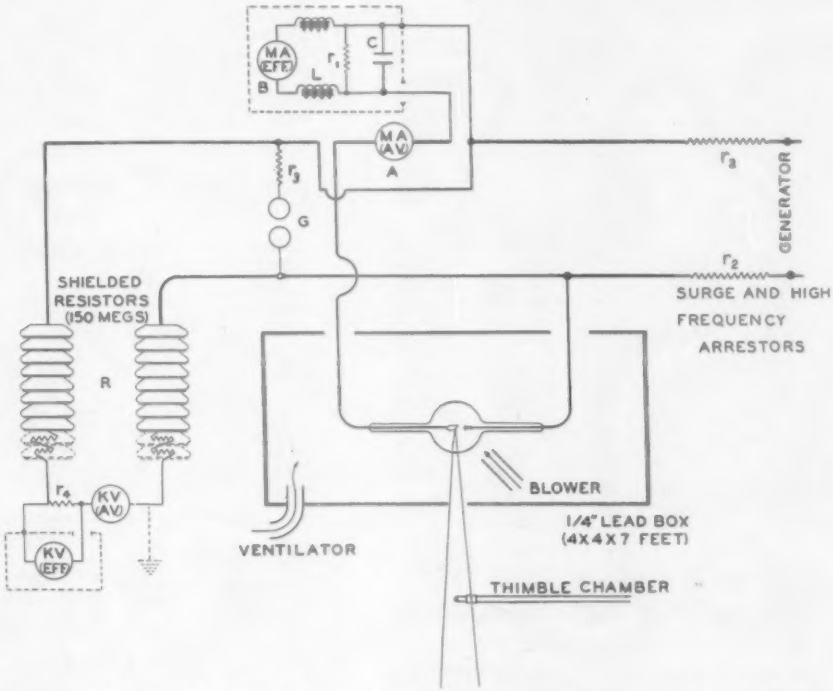

Fig. 1. Diagram of apparatus showing voltage and current measuring equipment.

The tube output was measured in roentgens per minute by means of a calibrated thimble ionization chamber kept in a fixed position with respect to the filters and tubes. The distance from the center of the chamber to the center of the focal spot was 50 cm., and at 15 cm. from the chamber were placed the limiting aperture and a

[15] See footnote No. 9.

[16] Taylor, L. S. *Bur. Standards J. Research*, 1930, *5*, 609 (R. P. 217).

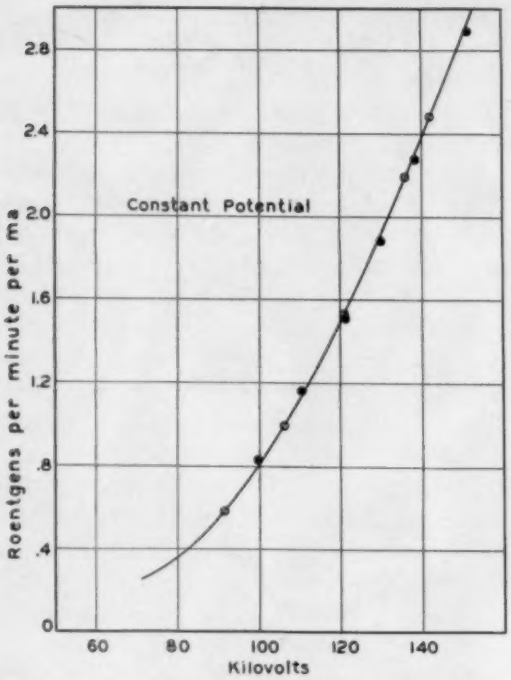

FIG. 2. Roentgen-ray output as a function of applied "constant potential" for 1 per cent and 10 per cent ripplage.

permanent filter (except during the determination of absorption curves) of 0.557 mm. of copper, plus 1 mm. of aluminum[17] on the side next to the chamber. Earlier tests showed that secondary radiation from the filter at this distance had no influence on the ionization measurements. The diameter of the beam at the chamber was 5.5 cm. throughout. To show the effect of the cross sectional area of the beam upon the measurements, it was found that when a beam diameter of 14.5 cm. was used there was an increase in ionization of 9.0 per cent for all voltages applied to the tube. This increase may be ascribed to the inclusion of stem radiation which had been cut off by the smaller aperture. In order that measurements made at different times might be directly comparable, all ionization current readings were corrected to a normal atmospheric condition of 22°C. and 76 cm. mercury pressure.

[17] Compare with 0.535 mm. Cu filtration used in our earlier papers.

III. EXPERIMENTAL RESULTS

(a) *Output per average milliampere.*

Outputs per unit tube current were usually determined from two operating currents, 4 and 6 ma., to bring out the differences produced by changes in the tube load. Similar measurements made for smaller and larger tube currents show that the order of magnitude of the change in output per average milliampere with tube current is about the same at all currents up to 10 ma.

Figure 2 shows, for the two constant potential generators, *C* (dots) and *F* (circles), the output per average milliampere as a function of the peak voltage. The ripplage of these generators was about 10 per cent and 1 per cent, respectively, at the tube currents used. It will be noted, however, that the points for the two generators fall very closely along the same curve. This bears out previous findings that, for the type of measurement encountered in

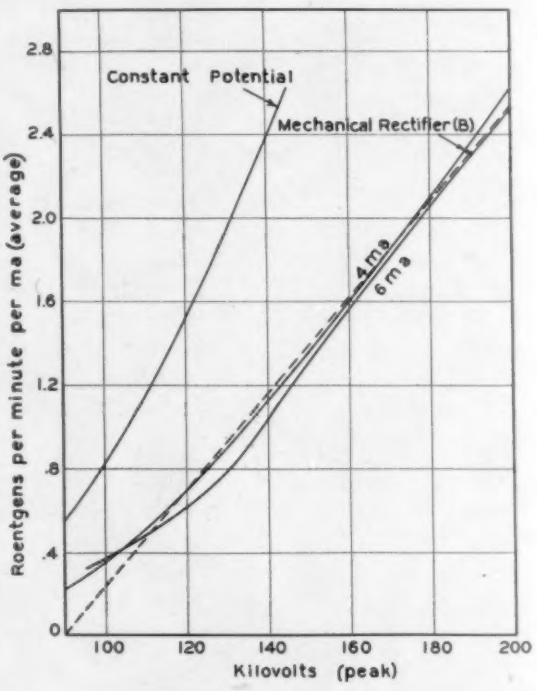

FIG. 3. Output per average milliampere as a function of the peak voltage for a mechanical rectifier. (To avoid confusion the actual data points are not plotted on this and most subsequent figures.)

therapeutic roentgen-ray work, the difference in roentgen-ray output between 1 and 10 per cent ripplage in constant potential generators is not greater than 1 or 2 per cent and is consequently of no significance.

The average and effective tube currents in Figure 2 were almost identical, as of course they should be. The peak voltages measured with a sphere gap were higher than the effective or average voltages by about the expected amount. This accounts for the 10 per cent ripplage in generator *C* as against 1 per cent in *F*. For closest agreement between the two generators, *F* and *C*, effective rather than peak voltages should of course be used, although the difference is seen to be small enough to be neglected for many purposes.

The output per average milliampere for the mechanical rectifier, *B*, is given by the curves in Figure 3 as a function of the peak voltage. Similar curves for the half-wave generator, *D*, are given by curves in Figure 4; and for the full-wave, *E*, and half-wave, *G*, generator by curves in Figure 5.

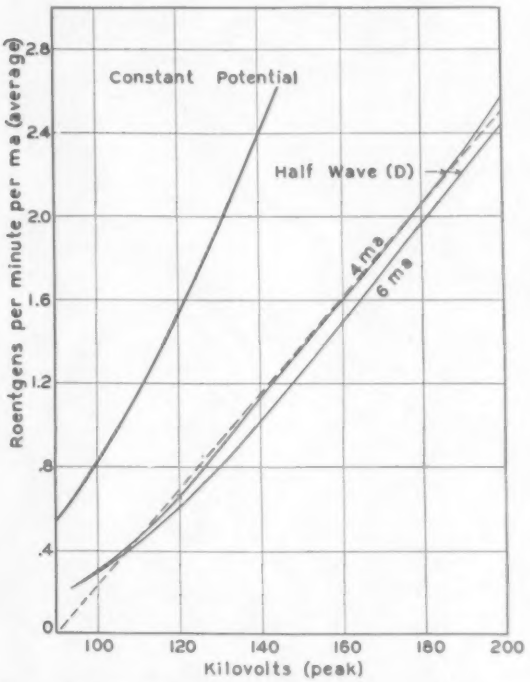

Fig. 4. Output per average milliampere as a function of the peak voltage of a half-wave valve tube rectifier.

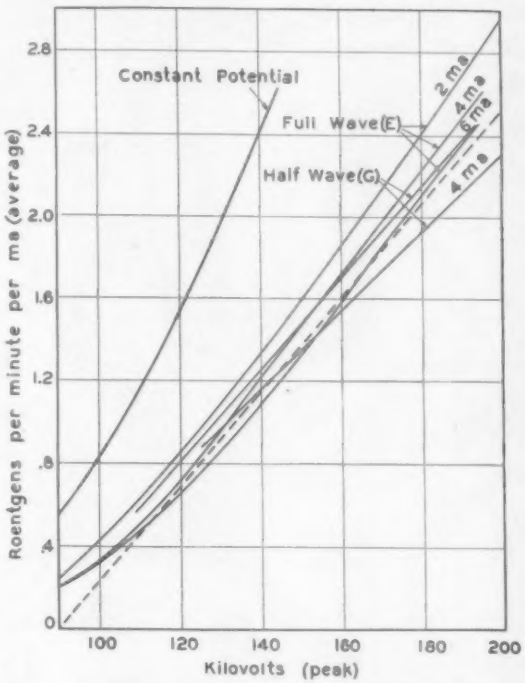

Fig. 5. Output per average milliampere as a function of the peak voltage for a half-wave and full-wave valve tube rectifier, using the same high tension transformer.

Curve *C* on each plot is for constant potential. The straight-dashed line is the same on all curves and is purely for reference to assist in comparing curves between different groups.

The first fact of significance is the same as reported by us in similar earlier studies,[18] namely, the very great difference between the output per average milliampere for constant potential as compared with all other wave forms.

For generators *B*, *D*, *E*, and *G*, the outputs per average milliampere are grouped within a comparatively narrow region. However, as the voltage increases the divergences between the several generators seem to be increasing, as well as the divergences between the outputs of the same generator under different loads. In fact, at 200 kv. (peak) there is, based upon this type of comparison, an output spread of about 25 per cent between the several generators.

[18] See footnote No. 8.

The variations between generators are in part due to differences in electrical regulation of the main transformer. Hence, to compare the half-wave and full-wave generators, the same transformer should be used. This was done with generator *E* for which the output curves are given in Figure 5. The results, which have been thoroughly checked, are not consistent with respect to load conditions. At 4 ma. (average) tube current there is an increasing divergence between the half- and full-wave generators, beginning at 1 per cent at 130 kv. (peak) and reaching 17 per cent at 190 kv. (peak). At 6 ma. there is a decreasing divergence in going to higher voltages, changing from 17 per cent at 130 kv. (peak) to 1 per cent at 190 kv. (peak). The impossibility of accurately comparing roentgen-ray generator outputs on the basis of average tube currents and peak voltages is confirmed.

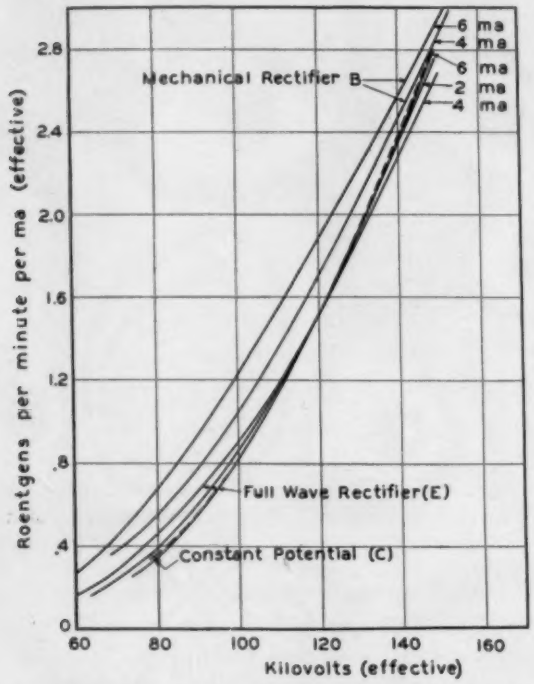

FIG. 6. Output per effective milliampere as a function of the effective voltage for a mechanical rectifier and full-wave valve tube rectifier.

There is thus no obvious relationship between the roentgen-ray outputs even when operated on the same transformer and accordingly in comparisons it is not strictly necessary to use identical transformers.

The only generalization that can be made from these data is that, if the tube currents are not varied over a range greater than ± 2 ma. (av.), the outputs of the various generator types will be the same within ± 15 per cent. It is, moreover, found that the output per average milliampere depends upon the particular tube current to such a degree as to render meaningless all comparisons between tubes and generators unless carried out at the same average current.

Many observers have been prone to compare generators or tubes under widely different load conditions, correcting the various outputs on the assumption that there is a linear relationship between roentgen-ray output and average tube current. For the usual roentgen-ray transformer, having characteristically poor electrical regulation, this assumption is far from correct. For example, it is not permissible to assume that, if the outputs of two generators at a given peak voltage differ by 20 per cent, the difference can be made up by increasing the tube current of one by 20 per cent, keeping the same peak voltage.

The observed difference in output per average milliampere between the half- and full-wave generator should ideally be nil, since to obtain the same average tube current with a half-wave generator as for a full-wave generator, over a number of cycles, the current during a single half-cycle need only be doubled throughout. However, in practice a marked difference is observed principally because of the large electrical regulation of the transformers. For, with the necessarily larger instantaneous values of the tube current in the half-wave generator, the resultant voltage wave form becomes so distorted as to produce a marked influence upon the roentgen-ray output. Furthermore, some roentgen tubes are purposely constructed by such a disposition of the focusing shield as to limit the space charge effect and so as to pass

only a narrow current wave. With such a tube the difference between a full- and half-wave generator is more marked.

(b) *Output per effective milliampere.*

Effective (r.m.s.) tube currents and voltages were obtained at the same time as the data just presented, hence are entirely comparable therewith. Values of the roentgen-ray output per effective milliampere, as a function of the applied effective voltage, are plotted in Figure 6 for generators B, C, and E. The broken line curve, C, is for constant potential. It is seen that, as with the earlier reports, the curves for the full-wave generator, E, follow very closely along the curve for constant potential, while those for the mechanical rectifier, B, approach the constant potential curve at higher voltages. At 150 kv. (effective) the total spread of the output per effective milliampere for all three generators is less than 10 per cent, while, for either B or E alone, with constant potential, it is less than 4 per cent.

It is thus indicated that the output per effective milliampere at the higher voltages is approximately the same for full-wave generators and constant potential. The previous studies show that the roentgen-ray quality for given effective voltages would likewise be the same.

Measurements of the effective (r.m.s.) voltage in half-wave generators have little significance except under ideal conditions which seldom exist in roentgen-ray circuits. This is because the effective voltage meter gives a root-mean-square value over a whole cycle, while only half the cycle is effective in the production of roentgen-rays—the other half being suppressed by the rectifier. If it were possible to measure the effective (r.m.s.) voltage during only the useful half-cycle, then the results would undoubtedly be directly comparable with those for a full-wave rectifier.

For a full-wave rectifier the effective voltage, E, (r.m.s.) is given by

$$E_{2/2}(\text{r.m.s.}) = E\,(\text{peak})\sqrt{\frac{\int_0^{2\pi}\sin^2\omega t\,dt}{2\pi}} \quad (1)$$

$$= \frac{\sqrt{2}}{2}E\,(\text{peak}) = .71\,E\,(\text{peak}).$$

For a pure sine wave this may be divided into two parts

$$E_{2/2}(\text{r.m.s.})$$

$$= E\,(\text{peak})\sqrt{\frac{\int_0^{\pi}\sin^2\omega t\,dt}{2\pi} + \frac{\int_{\pi}^{2\pi}\sin^2\omega t\,dt}{2\pi}}$$

$$= \frac{\sqrt{2}}{2}E\,(\text{peak}) = .71\,E\,(\text{peak}). \quad (2)$$

If, however, we consider one-half of the wave to be suppressed, and therefore useless, we have for a half-wave sine generator

$$E_{1/2}(\text{r.m.s.}) = \frac{\sqrt{2}}{2}E_{2/2}(\text{r.m.s.})$$

$$= .71\,E_{2/2}(\text{r.m.s.})$$

$$= .5\,E\,(\text{peak}). \quad (3)$$

We may apply this result to the ideal case of a half sine wave and full sine wave voltage of the same peak value. It would be observed that the r.m.s. voltage read over the full cycle on the half-wave generator must be multiplied by $\sqrt{2}$ to give the same r.m.s. voltage as for the full-wave generator.

The voltage wave form, however, in the usual roentgen-ray generator is not a pure sine wave (section d) because of the large electrical regulation of the transformer and the reaction of the roentgen tube. Analysis of the actual wave form by Fourier series would show each useful half-wave to correspond to a wave form having a predominant 3d harmonic and less important harmonics of higher order. We have then a complex wave form for which the r.m.s. voltage is no longer given by (2) but rather by the following:

$$E_{2/2}(\text{r.m.s.})$$

$$= \frac{1}{\sqrt{2\pi}}\sqrt{\int_0^{\pi}\left[\sum E_b \sin(b\omega t + \theta_b)^2\right]dt}$$

$$+ \int_{\pi}^{2\pi}\left[\sum E_b \sin(b\omega t + \theta_b)^2\right]dt. \quad (4)$$

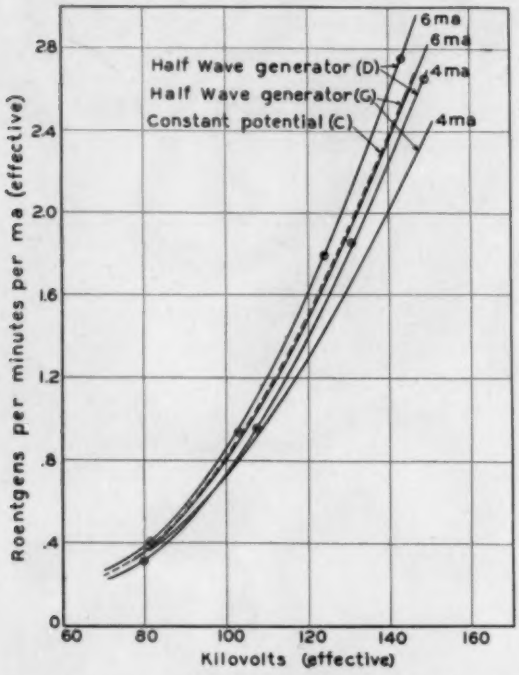

FIG. 7. Output per effective milliampere as a function of the effective voltage for two half-wave valve tube rectifiers, using different high tension transformers.

Solution of this equation for one half-wave only shows that equation (3) relating the r.m.s. value during a half-cycle to the r.m.s. value over a full cycle is valid only when there are no strong even harmonics present. Since, as pointed out, the wave form is composed predominantly of the 1st and 3d harmonics, we can, to a first approximation, obtain a measure of the effective voltage during the useful part of the cycle by multiplying the measured value by the $\sqrt{2}$. This type of correction is of course unnecessary for any phenomena utilizing the full cycle of the voltage wave, which includes all other common roentgen-ray generators.

By a similar procedure we should also correct the effective (r.m.s.) tube current readings to apply only during the useful half of the cycle. Making the same assumptions for the current wave form as were made for the voltage wave form, it is found that the r.m.s. current values over a full cycle as read on the meter, should be reduced by a factor of $\sqrt{\frac{1}{2}}$ which is equivalent to increasing the output per effective ma. during the useful half-cycle by the factor $\sqrt{2}$.

Outputs per effective milliampere, during the useful part of the cycle, obtained for the two half-wave generators *D* and *G*, are plotted in Figure 7 after the measured tube currents, and voltages were thus corrected by the factors $\sqrt{\frac{1}{2}}$ and $\sqrt{2}$, respectively. The broken line curve is for the same tube on constant potential. While the agreement between the three generators is not as close as in the case of the full-wave generators, the spread of the outputs, at a given voltage, is not nearly so large as in the case of equal peak voltages (Figs. 4 and 5). As shown below, the quality of these radiations at any given effective voltage is very nearly the same, thus bearing out our earlier findings on other generators.

(c) *Quality as related to voltage measurements.*

Ordinarily it has been assumed that at a given peak voltage, copper absorption curves obtained under different tube currents will be the same. This is based upon the further assumption that the output per

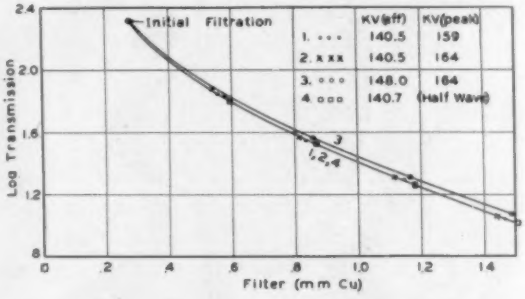

FIG. 8. Copper absorption curves showing the relationship between the roentgen-ray quality and the effective voltage as the tube load is changed.

average milliampere of a tube does not vary with the load. We have just shown, in the case of all but constant potential generators, that this assumption does not hold for changes in tube current even as small as 2 ma. On the other hand, it has been shown that at any tube current the quality

of the roentgen-ray beam is the same at a given effective (r.m.s.) voltage.[19]

The curves in Figure 8 show a very sensitive test of the relationship of quality to voltage. These were made with the full wave generator *E*, since in this case variations in tube current had the least effect on the output per milliampere. Curves 1 (dots) and 2 (crosses) were obtained respectively with the same effective voltage (140.5) but with peak voltages of 159 and 164 kv., the peak voltage change being caused by a change in tube current of 2 to 4 ma., respectively. Curves 2 and 3 (circles) were for the same peak voltage (164 kv.) but with respective effective voltages of 140.5 and 148 kv., and respective tube currents of 4 and 2 ma. From these, we see that (*a*) so long as the effective voltage is maintained constant, the absorption curves (hence roentgen-ray quality) are the same (curves 1 and 2); (*b*) a change in tube current of 2 ma., with the same peak voltage, causes an appreciable change of quality (curves 2 and 3).

Similar results were obtained using the half-wave generator *D*, after making correction as in section (b) for the suppressed half of the cycle which is ineffective in

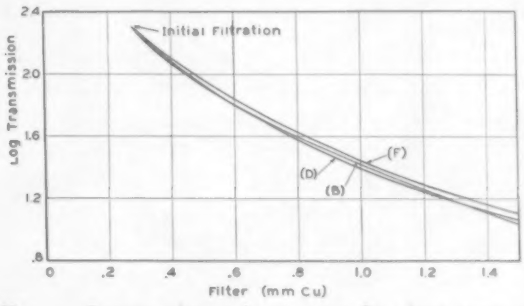

Fig. 9. Copper absorption curves for three generators of different type, operated at approximately the same effective voltage.
Generator *F*—141.7 kv. (effective)—143 kv. (peak).
Generator *B*—143.0 kv. (effective)—192 kv. (peak).
Generator *D*—144.0 kv. (effective)—180 kv. (peak).

roentgen-ray production. Curve 4 (squares) was obtained with the generator (*D*) operated at 99.7 kv. (effective, measured) or 140.5 kv. (effective, corrected), showing a

[19] See footnote No. 9.

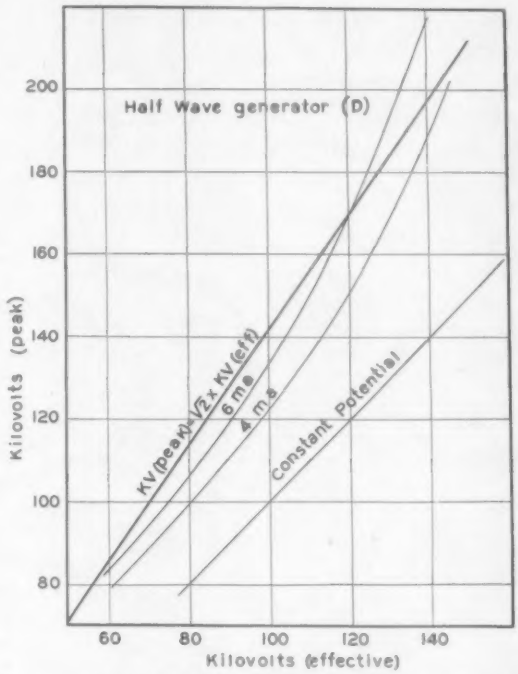

Fig. 10. Relationship between effective and peak voltage for a half-wave rectifier.

very close agreement between the qualities obtained with it and the full-wave generator (*E*).

Finally, Figure 9 gives the copper absorption curves for generators *F*, *B*, and *D* at approximately the same effective voltage but at widely different peak voltages, and shows the close relationship between the effective voltage and quality. The operating conditions are given in the legend. These curves show the qualities of the radiations to be the same; in section (b) it was found that the outputs per eff. ma. were practically the same, so it may be concluded that the radiations are essentially alike.

(d) *Changes in voltage wave form.*

Changes in the voltage wave form, brought about largely by poor electrical regulation of the transformer, appear to be the principal cause of the irregularity reported above. Information regarding the wave shape of the voltage applied to the tube may be obtained from the measurements already recorded, so that oscillographic examination of the wave form,

which is laborious under such varied conditions, need not be resorted to.

The general wave form may be inferred from the relationship between the effective (r.m.s.) and peak voltage. These are given in Figure 10 for the half-wave generator (*D*) and in Figure 11 for the half-wave (*G*)

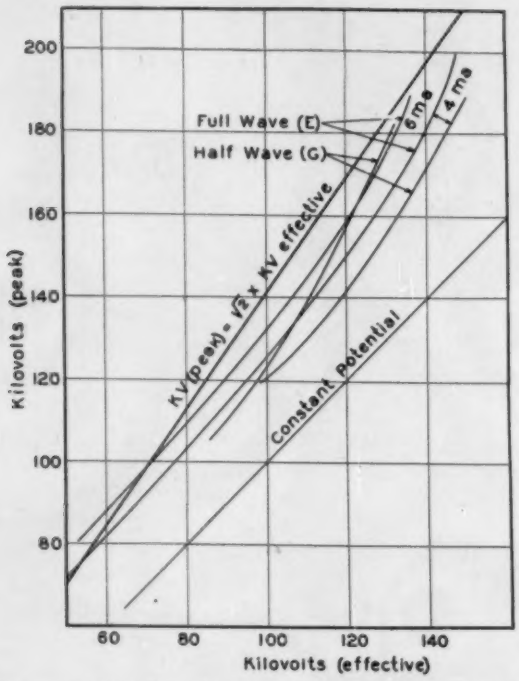

FIG. 11. Relationship between effective and peak voltage for a half-wave and full-wave valve tube rectifier, using the same transformer.

and full-wave (*E*) generator employing the same transformer.[20] The heavy straight line on each plot is for the case of a pure sine wave where kv. (peak) = $\sqrt{2}$ kv. (effective). It is evident that, where the curve for a particular generator and tube current lies below the line for a sine wave, a relatively broad flat-topped voltage wave form is indicated which approaches constant potential as the limit. Where the curve lies above the line kv. (peak) = $\sqrt{2}$ kv. (effective), a relatively narrow or peaked voltage wave form is indicated.

Thus, we find that if the tube current at a given peak voltage is increased, there is a marked decrease in the effective voltage, indicating a narrowing of the voltage wave form and causing a corresponding change in quality (a change corresponding to a lower constant potential). The effect on a given transformer in passing from full-wave to half-wave rectification is indicated by the curves in Figure 11. For a given average tube current of 4 ma. and the same peak voltage, an increase in the effective voltage in going from full- to half-wave is found. This indicates a broadening of the wave form and an increase in the hardness of the radiation; which is to be expected, since the half-wave generator draws a larger maximum tube current during the cycle and flattens out the wave.

These curves likewise show to what extent we may rely upon the assumption, involved in equation (3) and used in arriving at the effective voltage in the case of half-wave generators. For example, it is found in Figure 11, that the 6 ma. curve for generator *G* approaches nearer a sine wave value than the 4 ma. curve; hence should yield more nearly the normal output per milliampere at that effective voltage. This is found to be the case for the same 6 ma. in Figure 7.

IV. CONCLUSIONS

The experimental results presented in this paper corroborate in detail and further extend our earlier findings regarding the relationships between roentgen-ray tube output and the applied voltage and current supplied by different types of high voltage generator, in the following essentials:

1. For a given effective (r.m.s.) tube voltage, the roentgen-ray outputs per effective milliampere of tube current for all roentgen-ray generators are much more nearly the same than for any other type of voltage and current measurement. The variation of output per effective milliampere with tube current is small; hence, results obtained at one tube current are comparable with results obtained at some other tube current.

2. Roentgen-ray qualities at a given ef-

[20] Similar curves for generator *B* are given in Figure 7*B* of Research Paper No. 491.

fective voltage are nearly the same for all generators. This means, in effect, that the output and quality of any generator may be reduced to terms of an equivalent output and quality obtained with constant potential which, in itself, is perfectly definite.

3. Ripplage in constant potential generators of 1 to 10 per cent causes no appreciable differences as far as concerns the usual quality and quantity measurements.

4. Effective (r.m.s.) current and voltage measurements on a half-wave generator must be suitably corrected for the useless half-cycle when using the customary types of r.m.s. reading meters.

5. In the comparison of half-wave and full-wave generators with constant potential at given peak voltages and tube currents, there is no simple relationship between the roentgen-ray output or quality.

6. The specification of roentgen-ray output in terms of average tube current and peak voltage is indefinite because of voltage wave form distortion with change in load.

This investigation has been made possible through the cordial cooperation of the American x-ray equipment manufacturers, to whom we express our appreciation.

ENERGY CONSIDERATIONS IN HIGH VOLTAGE THERAPY

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ABSTRACT

The relation between roentgens and energy is discussed, and the energy per cm.^{2} per roentgen plotted for the range 100 to 2,200 kv. Calculated values of attenuation and absorption coefficients are given for the same range.

The number of roentgens required to produce an erythema is calculated on certain assumptions which cannot be justified theoretically, but give fair agreement with observation. The total energy delivered under the same conditions is calculated.

QUANTITY OF RADIATION

MUCH has been said and written both for and against the roentgen unit, but the fact remains that its use provides the only convenient method available for measuring the quantity of radiation, or, as it is called, the x-ray dose. The dose in roentgens can be measured quite readily and with sufficient accuracy for all practical purposes and we can reasonably expect that a given number of roentgens will always produce the same effect under the same conditions. This is satisfactory in practice as long as the problems dealt with are similar in nature and the quality of radiation is the same, but we have no right to expect that a given number of roentgens will produce the same effect regardless of the quality of the radiation. As a matter of fact, we can expect this to be so only in very special cases. It is much more reasonable to assume that equal effects are produced when equal quantities of energy are absorbed in a given volume. We cannot assert, offhand, that this must be true, but we can assume that it is true and see if it leads to conclusions which agree with observation. The assumption appears to be reasonable if we confine ourselves to hard radiation so that we may neglect the effect of photo-electrons completely. The error in so doing is at most a few per cent. Our assumption becomes still more reasonable when we consider the case of a fairly large beam directed against an absorbing body sufficiently large to absorb all or nearly all of the energy in the beam, for then, as the radiation in the hard beam becomes degraded by scattering, a large fraction is ultimately absorbed as radiation of the same quality as the softer beam.

Such differences as seem to exist between single and multiple celled organisms in regard to their sensitiveness to radiation at different wave lengths is of no importance in the case here considered, for in practical application of roentgen rays in deep therapy we are dealing with a heterogeneous mass of highly complex material, and the best we can do is to assume that the destruction in a given volume is proportional to the energy absorbed in this volume, the proportionality factor depending on the type of cell, but not on wave length.

QUALITY OF RADIATION

By quality of radiation we mean the spectral distribution of the energy. The short wave limit depends only on the maximum voltage applied to the roentgen tube, whereas the distribution of energy depends on the voltage source, target material, and on the kind and thickness of filter. If it is desired to use hard radiation, high voltage together with filters of high atomic numbers is required. In the wave length region with which we are here concerned, the photo-electric absorption is still important in the case of elements of high atomic numbers such as lead, gold, and platinum, and we can therefore take advantage of the

preferential absorption of the longer wave lengths. Therefore, the higher the atomic number of the filter is, the harder will the radiation be for a given sacrifice in energy.

As the action of the filter is purely to attenuate by scattering or absorption the softer part of the radiation, more than the harder, we cannot have hard radiation left unless it was there to start with, and it is therefore important that we start out with a spectrum which is as rich as possible in hard radiation, if hard radiation is desired. The hardest radiation produced depends only on the maximum voltage, but the amount of energy in the form of hard radiation depends on the shape of the voltage and current wave. Thus the spectrum which is richest in hard radiation is produced when the potential on the roentgen tube is always at maximum when current flows through the tube. This is the case when constant potential is used or with alternating voltage, if the filament is arranged to furnish electrons only when the voltage is at or near its maximum value.

As far as the quality of radiation is concerned, there is thus little choice between constant and alternating potential. Rectification has, of course, no influence on the spectrum, provided the rectifier is satisfactory. With the mechanical rectifier as generally used, it is another matter. There, as with the induction coil, the voltage wave is usually so steep, i.e., of so short duration, that very little hard radiation is produced.

It is not usually convenient to specify the spectral distribution of energy in a roentgen-ray beam and for this reason it is practical to characterize the beam by its equivalent wave length or equivalent voltage. By the equivalent wave length λ_e we mean that wave length of monochromatic radiation which has some predetermined measurable property, in common with the beam in question. For our present purpose, the property most suitable would seem to be the attenuation in water.

The equivalent voltage V_e is then the voltage required to produce radiation of the equivalent wave length and is given by Einstein's equation:

$$(1) \qquad h\nu = eV$$

$$(2) \qquad V_e = \frac{hc}{e\lambda_e} = \frac{12354}{\lambda_e}$$

V_e in kilovolts and λ_e in x-units. 1 x-unit $= 10^{-3}$ Å $= 10^{-11}$ cm.

The calculations to follow are made for

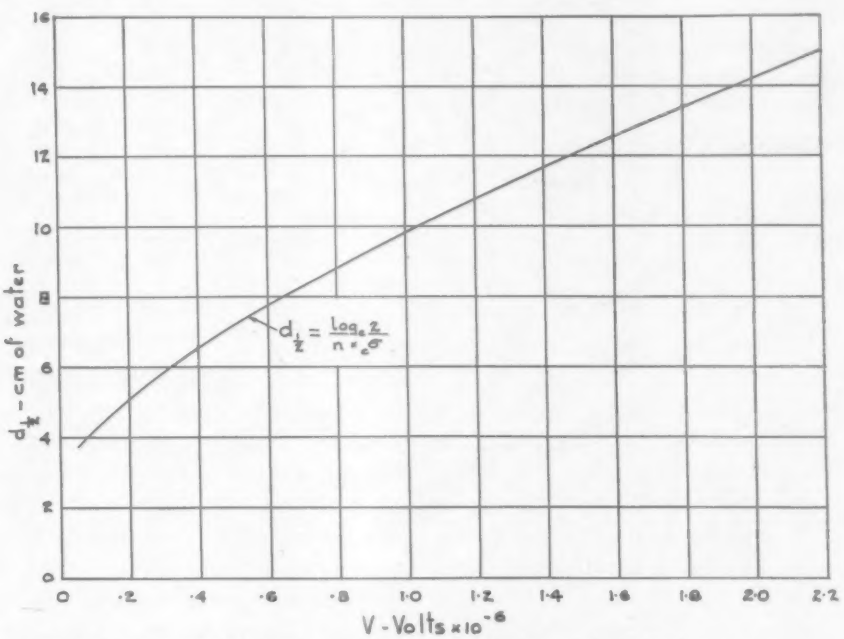

Fig. 1. Calculated half-value layer of water for monochromatic radiation 100 to 2,200 kv.

monochromatic radiation and it is clear that they hold closely only for this case. We may, however, assume that the equivalent wave length as here defined has sufficient meaning to permit us to draw conclusions as to the effects of a heterogeneous beam of radiation, such as we are forced to use in practice.

equivalent voltage is then determined by comparing the measured value of $d_{1/2}$ with the half-value layer of water for monochromatic radiation. In Figure 1 are shown half-value layers of water for monochromatic radiation from 100 to 2,200 kilovolts. The curve has been calculated by using values of the attenuation coefficient de-

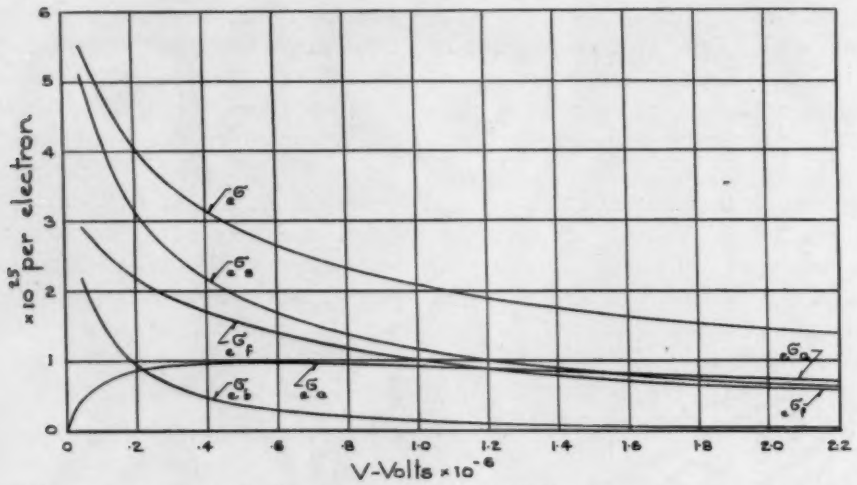

FIG. 2. Scattering per electron calculated from the Klein-Nishina formula. Monochromatic radiation. $_e\sigma$ = total attenuation; $_e\sigma_s$ = total scattered radiation; $_e\sigma_f$ = forward scattered radiation; $_e\sigma_b$ = backward scattered radiation; $_e\sigma_a$ = true absorption, recoil electron.

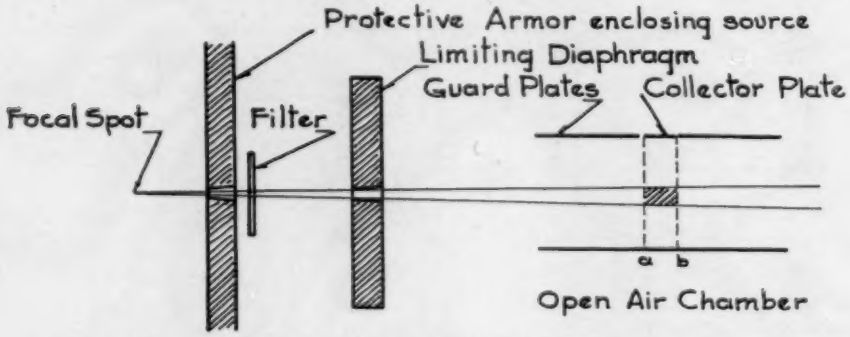

FIG. 3. Arrangement for measuring radiation in roentgens.

The attenuation in water of the radiation from a roentgen tube is most conveniently determined by measuring the half-value layer of water. This is done with the tube operated as it is to be used, and the filters in place. A very small beam must be used and care must be taken that only the direct beam enters the measuring chamber. The

termined from the formula given by Klein and Nishina.[1]

In Figure 2 the curve marked $_e\sigma$ is the attenuation coefficient thus determined. We have checked the value of $_e\sigma$ with monochromatic radiation of wave length $\lambda = 24$ x-units and found it accurate within the

[1] Klein O., and Nishina, Y. *Ztschr. f. Physik.*, 1928, *52*, 867.

probable error of the measurement which is about 2 per cent.

THE ROENTGEN

Before entering upon our main theme, the absorption of radiation in water, it is necessary to discuss the measurement of radiation in roentgens and to convert roentgens into units of energy, i.e., ergs. When a quantity of radiation in the form of a small beam of homogeneous roentgen rays falls upon a substance such as air, the beam, in passing through a thin layer of the substance, will be attenuated by the amount

(3) $$E = {}_e\mu n E_0$$

Where E_0 is the energy falling on the layer, while n is the number of electrons in the layer, ${}_e\mu$ is the attenuation coefficient per electron and may be written

(4) $${}_e\mu = {}_e\tau + {}_e\sigma$$

Here ${}_e\tau$ is the photo-electric absorption coefficient per electron and can be neglected in air when V_e is greater than 100 kv. ${}_e\sigma$ is the energy per unit of energy of the beam which is removed by each electron in interactions in which the energy is divided between the electron and degraded radiation. We can therefore express the attenuation coefficient

(5) $${}_e\mu = {}_e\sigma = {}_e\sigma_a + {}_e\sigma_s.$$

Where ${}_e\sigma_a$ is the true absorption coefficient per electron, i.e., fraction of energy taken up by the electron, while ${}_e\sigma_s$ represents the energy in the degraded radiation. Figure 3 shows schematically an arrangement suitable for measuring hard x-rays in roentgens. A small, well-defined beam is used, and the limiting diaphragm must be so arranged that scattered roentgen rays and electrons from the filter, as well as from the diaphragm, are prevented, as far as possible, from reaching the measuring volume between (a) and (b). For other precautions, reference may be had to the very careful investigations by Dr. Lauriston S. Taylor of the U. S. Bureau of Standards. Under these conditions, the number of ions formed between (a) and (b), and collected on the collector plate, can be assumed to be proportional to the energy actually absorbed in the shaded volume between (a) and (b). It is true that many of the recoil electrons which start out in the shaded volume are not completely absorbed between (a) and (b), but this loss is exactly compensated by the gain of electrons which originate in front of (a).

It is advisable to construct the measuring chamber of aluminum or other light material and to avoid the use of lead around the chamber. If the diameter of the beam is small, say less than 1 per cent of the distance in which the radiation loses one-half its energy, then the fraction of degraded radiation which is absorbed in the measuring volume directly, or scattered back from the surroundings, may be neglected, and the energy E_a actually absorbed per cm.^{3} in the shaded volume is

(6) $$E_a = {}_e\sigma_a E_0 n_a$$

E_0 being the energy per cm.^{2} of the beam at the point where the measurement is made, say at (a) $n_a = 3.92 \times 10^{20}$ is the number of electrons per cm.^{3} in the air. It is difficult to measure E_a directly in energy units, but we can calculate the energy if we know the number of ions produced by the recoil electrons originating in 1 cm.^{3}, for each ion removes 32 electron volts from the recoil electron and therefore 1 e.s.u., in the form of ions, requires that an energy of $32/300 = 0.107$ ergs shall have been absorbed in 1 cm.^{3}. But by definition, the quantity of radiation which produces 1 e.s.u. in 1 cm.^{3} of air, is 1 roentgen, so we have

(7) $E_a = 0.107$ ergs per cm.^{3} per roentgen.

Let R be the number of roentgens delivered at the point (a), then

(8) $E = 0.107\ R$ ergs will be absorbed per cm.^{3} at the point (a)

Combining this result with equation (6) we see that

(9) $E_0 = \dfrac{0.107\ R}{n_a {}_e\sigma_a}$ is the number of ergs delivered per cm.^{2} at the point (a) when the total quantity of radiation is R roentgens.

$_e\sigma_a$, the scattering absorption coefficient per electron, may be calculated by making use of the expressions for the distribution of the scattered energy developed by Klein and Nishina.[1] The calculated values of $_e\sigma_a$ for several wave lengths are plotted in Figure 2 against V as abscissa. Inserting these calculated values in equation (9), and taking $R=1$, we obtain the actual energy in ergs per cm.^{2} for a quantity of radiation equal to 1 roentgen. This is shown in Figure 4. It is not safe to extrapolate this curve much below $V=100$ kv. because of the photoelectric absorption which we have neglected.

By a broad beam we mean a beam, the diameter of which is at least equal to the distance in which the energy is reduced to one-half.

As in the previous case, it is important for our consideration that the filter and the limiting diaphragm do not contribute much scattered radiation to the absorbing body. This condition is best fulfilled if the absorber is some distance from the limiting diaphragm. Under these conditions we permit a quantity of radiation equal to R roentgens to fall on the surface of the absorber.

We shall now determine the number of

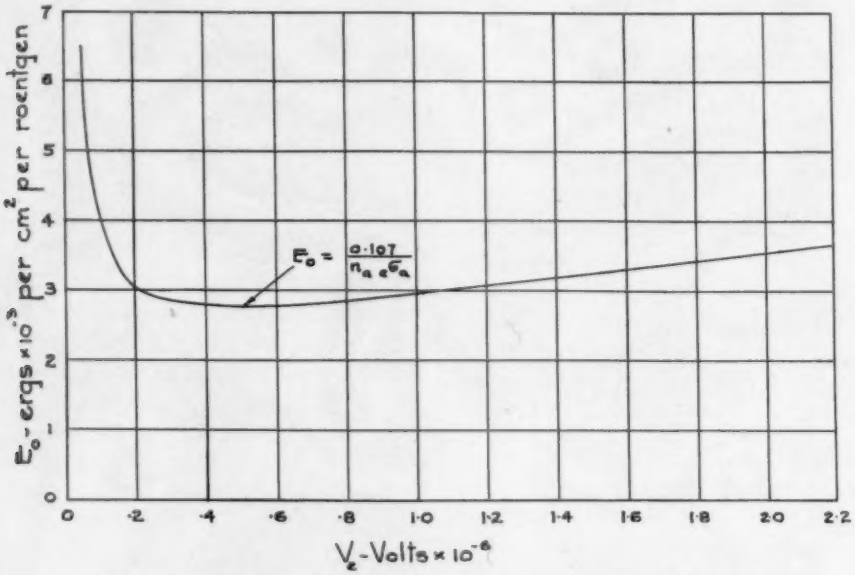

Fig. 4. Total energy falling on 1 cm^2. when 1 roentgen is delivered.

Absorption in Water

The general problem of absorption in a large body is extremely complex and it is doubtful if we should gain much useful information by attempting a detailed solution. It seems, therefore, advisable for our present purpose, to limit ourselves to conditions such as are used in deep therapy, and apply certain general energy considerations to the case.

We consider a broad beam of x-rays falling upon a body sufficiently large to absorb nearly all of the energy in the beam. roentgens required at various wave lengths, if it is desired that a constant amount of energy shall be absorbed per cm.^{2} of a surface layer, say 1 mm. thick.

The energy absorbed in this surface layer is given approximately by

$$E_s=(_e\sigma_a+_e\sigma_b)n_sE_0 \qquad (10)$$

where $_e\sigma_aE_0$ as before, is that fraction of the energy which is absorbed by the recoil electron, while $_e\sigma_bE_0$ is the fraction which is scattered backward in the form of radiation, n_s is the number of electrons per cm.^{2}

of the surface layer under consideration. For water $n_s = 3.36 \times 10^{22}$ electrons. That we must here use ${}_e\sigma_b$ rather than ${}_e\sigma_s = {}_e\sigma_b + {}_e\sigma_f$ is seen, when we consider that the fraction ${}_e\sigma_b E_0$ is either absorbed in the surface layer, or compensated for by radiation which is scattered back from layers farther on along the beam, while ${}_e\sigma_f E_0$ being the fraction scattered forward, is not compensated for, and thus does not contribute to the surface absorption. It is true that the compensation is not complete, owing to the attenuation of E along the path, but the deficiency will tend to balance the effect of multiple scattering and ultimate absorption of the degraded radiation photoelectrically.

Klein and Nishina have developed an expression for the energy of scattered radiation per unit solid angle as a function of the wave length.

If we integrate this expression between the limits $\pi/2$ and π and evaluate the integral for several values of V, we obtain the curve marked ${}_e\sigma_b$ in Figure 2.

Returning now to equation (10), and using the value of E_0 given by equation (9), we get

$$(11)\quad R = E_s \frac{{}_e\sigma_a}{{}_e\sigma_a + {}_e\sigma_b} \cdot \frac{n_a}{n_s} \cdot \frac{1}{0.107} \text{ roentgens.}$$

Here all quantities are known and we may determine R for any desired value of E_s and V_e. This has been done for $E_s = 1.4 \times 10^4$ ergs per cm.^{2} in a layer 1 mm. thick for a number of wave lengths and the results plotted in Figure 5.

The values chosen for E_s and for the thickness of the layer considered are, of course, somewhat arbitrary, and we should therefore not attach too much significance to the numerical values given in the plot. The general trend, however, is quite clear, and relative values are uncertain only because of the uncertainty involved in setting the absorption coefficient equal to ${}_e\sigma_a + {}_e\sigma_b$. This would seem to be a sufficiently close approximation for our purpose, although certainly not entirely justifiable on theoretical grounds.

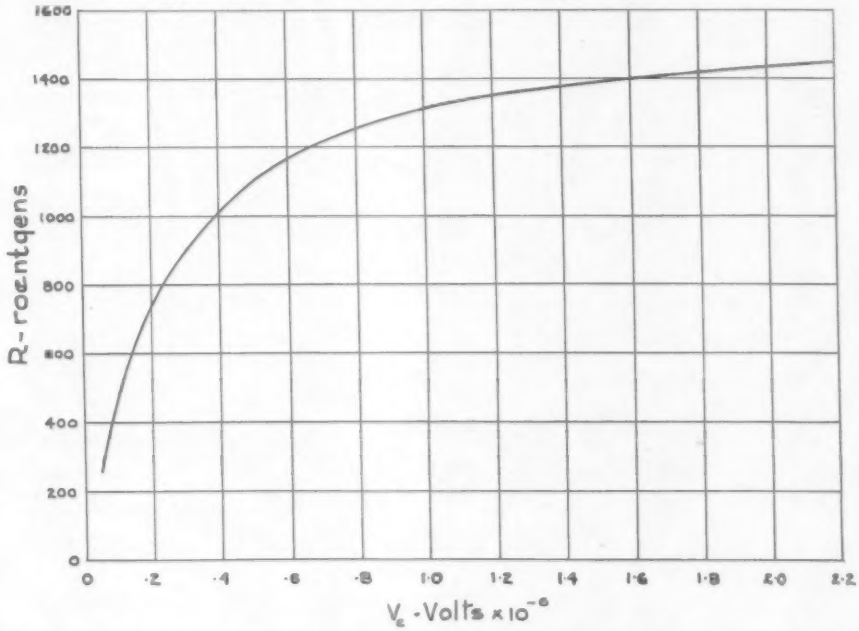

Fig. 5. Total number of roentgens required to cause absorption of 1.4×10^4 ergs per cm.^{2} of a surface layer 1 mm. thick. Calculated. A curve of the erythema dose can be expected to be similar.

It is an interesting fact that in the region below 1,500 kv., on the average very nearly

half of the energy in the interaction between the radiation and an electron is given to the electron or scattered backward while the other half is scattered forward. By using the values shown in Figure 2, it may be seen that the maximum deviation from this rule is less than 5 per cent, so that we may write

$$(12) \qquad {}_e\sigma_a + {}_e\sigma_b = {}_e\sigma_f = \tfrac{1}{2}\,{}_e\sigma$$

Instead of equation (10) we can therefore write

$$(13) \qquad E_e = \tfrac{1}{2}\,{}_e\sigma n_e E_o$$

spectral distribution of energy is such that the equivalent voltage is about one-half to two-thirds of the maximum voltage, depending on the filtration. Keeping this in mind, we see that the curve in Figure 5 represents fairly well the number of roentgens required to produce an erythema of the skin with the various kinds of radiation employed in deep therapy.

It is interesting now to determine the total amount of energy which under these conditions has been delivered to the body for each cm.² of surface. This we obtain most simply by solving equation (10) for

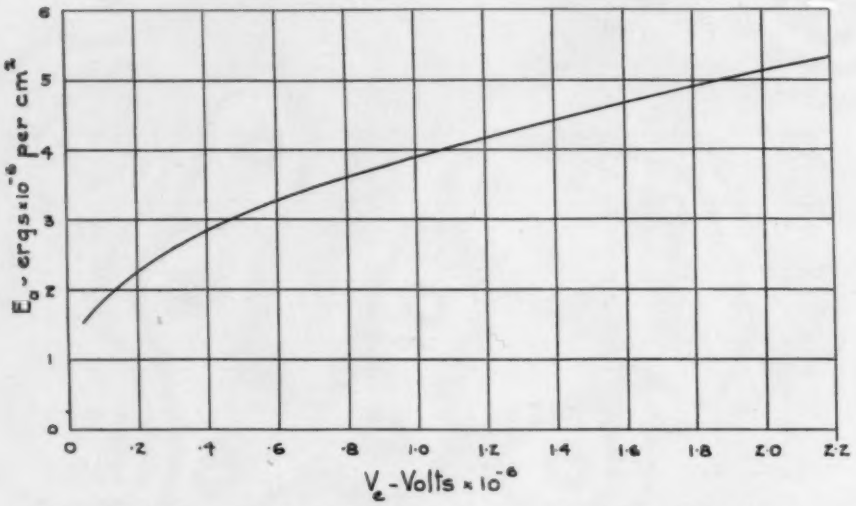

Fig. 6. Total energy delivered for constant absorption in the surface layer.

This would not change the curve in Figure 5 appreciably.

The curve in Figure 5 thus represents the number of roentgens which at a given wave length must be delivered in order that 1.4×10^4 ergs may be absorbed per cm.² of a surface layer 1 mm. thick. If, now, this absorbing body is the human body, and if we assume that 1.4×10^4 ergs absorbed per cm.² of the skin produces a certain recognizable reaction on the skin, then we should expect that this effect will be produced when we deliver the number of roentgens given by the curve in Figure 5 for x-rays of a given equivalent voltage.

In the usual type of x-ray equipment, the $E_e = 1.4\times10^4$ ergs per cm.², thus obtaining E_0 as a function of the equivalent voltage. The results of this computation are shown in Figure 6 which therefore may be taken to represent the relative merits of radiation of various degrees of hardness, on the assumption that we are interested solely in delivering the greatest amount of energy possible with a given skin effect.

In the case of deep-lying tumors, say 10 or more cm. below the surface, the comparison obviously is even more in favor of the hard radiation. The soft radiation is attenuated so rapidly that most of the energy is used up in destroying the overlying normal tissue and very little is ab-

sorbed in the tumor. This is particularly important when small ports are used, as the attentuation is then greatest. It is for this reason that the radiologist who attempts to use low voltage equipment for deep therapy work finds himself forced to use large portals, and he does not have an opportunity to use his skill and judgment in using multiple portals adapted to the particular case in hand.

Since the present paper was submitted for publication, the author has thought it of interest to treat in a similar manner the voltage range in which the photo-electric absorption is not negligible. This will be presented in a subsequent paper to appear in an early issue of this Journal.

THE PHYSICAL FOUNDATIONS OF CHEST ROENTGENOGRAPHY*

PART II. THE DEPENDENCE OF SHARPNESS UPON MOVEMENT OF LUNG TISSUES AND SIZE OF FOCAL SPOT

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ROCHESTER, NEW YORK

THE movement of the lung tissues with the heart beat, and the limitations in the ability of the focal spot to stand, without damage, the energy applied to the roentgen tube, constitute the most difficult phase of the problem of definition or sharpness in chest roentgenography. Practically the whole of the electrical energy used for the production of roentgen rays is concentrated on the focal spot. A tiny fraction of this energy emerges from the focal spot in the form of roentgen rays, but the remainder serves merely to heat a thin layer of metal of the area of the focal spot. This heat is radiated and conducted away rather slowly, so that, in the case of short exposures, the immediate effect is to cause a rapid rise in temperature of the focal spot surface. Tungsten, the metal commonly used for the active face of the target, has the highest melting point of any metal known and can safely be heated to a higher temperature than any other target material. Even so, the focal spot on a tungsten target must be large enough to affect very noticeably the sharpness of roentgen-ray shadows.

The power that may be applied to a given size of focal spot increases slightly as exposure time is decreased,[2] but, in the main, the increased tube currents necessitated by shorter exposure times must be accommodated by a nearly proportional increase in area of focal spot. The larger focal spot offsets, to a greater or less degree, the gain in sharpness secured by shortening the exposure time. How, then, should exposure time and focal spot size be mutually adjusted to secure the best resultant roentgenographic sharpness?

In an ingenious method of attacking this problem developed by Bouwers,[3,4] an analysis was made of the way in which various factors influence the degree of diffusion of the edge of a shadow as projected upon the film. The edge of any shadow in the roentgenogram may be diffused by reason of geometric factors, such as the size of the focal spot combined with the relative distances of the object and the focal spot from the film. The edge of the shadow may also be diffused by the movement of the object during the exposure. Any such diffusion may cause the edge of the shadow to have a perceptible width. If this width is small, e.g., less than 0.1 mm., it appears fairly sharp to the naked eye; but if it is wider than 0.1 mm., as is usual in roentgenography, it appears more or less diffuse.

The width of the diffuse edge of a shadow may be called the unsharpness. If the object of interest in the roentgenogram, such as a portion of lung tissue, moves during the exposure, the edge of the shadow of the object is diffused to the extent that the shadow has moved. This distance is the product of the speed of movement and the exposure time. For instance, if the speed of movement is 10 mm. per second, and the exposure time 1/5 second, the shadow has moved 1/5 of 10 mm., or 2 mm. The width of diffusion of the edge of a shadow arising from movement is called *movement unsharpness*. Movement unsharpness is illustrated in Figure 1(*a*) which assumes a point source of roentgen rays.

If the object is stationary during the exposure, movement unsharpness is avoided, but the edge of its shadow may be diffused somewhat because of the size of the focal spot and the distance of the object from the film. In this case the diffusion at the

* Communication No. 508 from the Kodak Research Laboratories.

edge of the shadow is the penumbra formed by the width of the focal spot, as illustrated in the diagram of Figure 1(*b*), and is called *geometric unsharpness*. If *d* is the width of the focal spot, *OF* the object-film distance, and *OT* the object-target distance, geometric unsharpness, U_g, is equal to $OF/OT \times d$.

THE CALCULATION OF UNSHARPNESS

It is of interest to calculate movement unsharpness, geometric unsharpness, and total unsharpness for a series of exposure times, assuming typical conditions used in chest roentgenography. From data to be discussed later, a figure for a typical velocity of movement of lung tissue may be

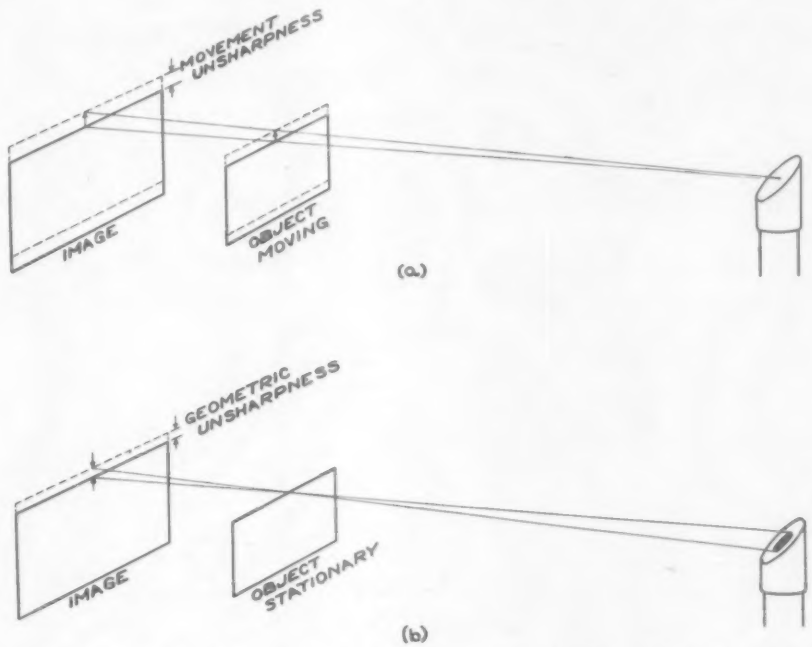

FIG. 1. (*a*) The edge of a shadow is blurred by movement to the extent that the shadow has moved during the exposure, giving rise to movement unsharpness. (*b*) The edge of a shadow may also be diffused by the size of the focal spot and the distance of the object from the film; the width of the penumbra at the edge of a shadow is designated as geometric unsharpness.

The total width of the diffuse edge of a shadow, owing to the combination of the effects of movement of the object and the penumbral shadow cast by the focal spot, is equivalent to the sum of the movement unsharpness and geometric unsharpness (Fig. 2), and is called *total unsharpness*.

Movement unsharpness may be diminished by shortening the exposure time; however, this must be accompanied by an increase in tube current in order to afford adequate exposure of the roentgenogram. The increase in tube current makes necessary an enlargement of the focal spot, with a resulting increase of geometric unsharpness.

taken as 5 millimeters per second. At 80 kv.p. and 6-foot target-film distance, with photographic materials of average speed, an exposure of 20 milliampere-seconds should be ample for the majority of chests. The calculations will be made for a portion of lung tissue 4 inches from the film (object-film distance = 4 inches). A line focus tube, with anode slope of 20 degrees, is assumed, with a focal spot which appears square as viewed along the path of the central ray. Data supplied by Bouwers[2,4] are used in computing the size of focal spot and the resulting geometric unsharpness corresponding to each exposure time. The results are recorded in Table 1.

The values of movement unsharpness show that, with a lung tissue speed of 5 millimeters per second, an exposure of 1/40 or 1/60 second is short enough to make the movement practically imperceptible in the roentgenogram. However, at 1/60 second the increase in geometric unsharpness more than offsets the decrease in movement unsharpness, with the result that total unsharpness is actually higher at 1/60 second than at 1/40 second. In fact, the minimum value of total unsharpness occurs at 1/30 second, and at 1/20 second the total unsharpness is effectively the same as at 1/30 second. Altogether, the 1/20 second exposure is to be preferred over the 1/30 second, since it permits a slightly smaller focal spot and consequently better definition in the more slowly moving portions of the lungs.

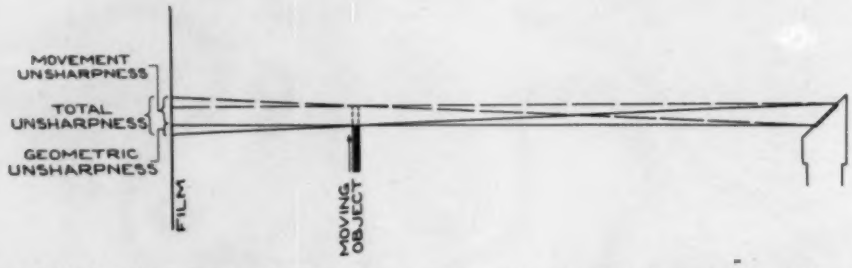

FIG. 2. Total unsharpness is the sum of movement unsharpness and geometric unsharpness.

Bouwers[3] derived a series of equations from which calculations such as those recorded in Table 1 may readily be made. Movement unsharpness is given by

$$U_m = at \qquad (1)$$

where a is the speed of movement in millimeters per second and t is the exposure time.

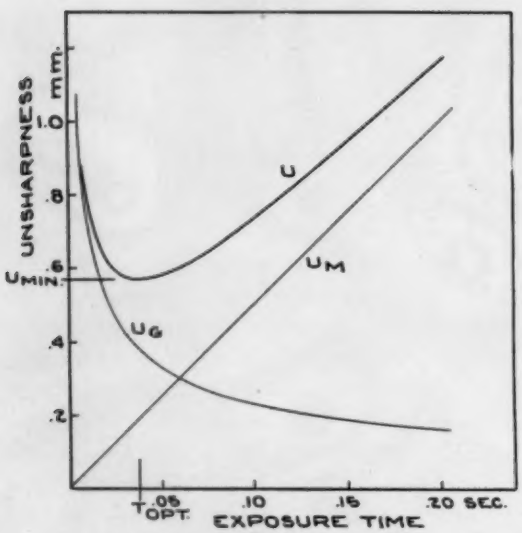

FIG. 3. Unsharpness due to focal spot size (U_g), unsharpness due to movement (U_m), and total unsharpness ($U = U_g + U_m$) as a function of exposure time. These curves are drawn to fit the following conditions; exposure of 20 ma-sec. at 80 kv.p.; 6-foot target-film distance; 4-inch object-film distance; speed of lung tissue movement 5 mm. per sec.; line focus tube with 20-degree anode slope.

TABLE I

Exposure Time Seconds	Movement Unsharpness Millimeters	Geometric Unsharpness Millimeters	Total Unsharpness Millimeters
1/4	1.25	0.16	1.41
1/10	0.50	0.23	0.73
1/20	0.25	0.33	0.58
1/30	0.17	0.40	0.57
1/40	0.12	0.47	0.59
1/60	0.08	0.58	0.66
1/120	0.04	0.82	0.86

Geometric unsharpness is given by the expression

$$U_g = \frac{\overline{OF}\sqrt{E}}{\overline{OT}\sqrt{Bt}} \qquad (2)$$

where OF is the object-film distance, OT the object-target distance, E is the energy

passed through the focal spot during the exposure expressed in watt-seconds, B is the specific load capacity of the focal spot expressed in watts per square millimeter effective target area, and t is the exposure time. The energy of the exposure E is the product of kilovolts (effective), milliamperes, and exposure time.

The total unsharpness is the sum of the geometric unsharpness and the movement unsharpness, or

$$U = U_g + U_m. \qquad (3)$$

Figure 3 shows typical curves of U_g and U_m plotted aginst exposure time. Curve U_g shows how geometric unsharpness diminishes with increase of exposure time because of the fact that a longer time permits a smaller tube current and therefore a smaller focal spot. Curve U_m shows how movement unsharpness increases in proportion to the time of exposure. The curve for total unsharpness U is found by adding the corresponding values of U_g and U_m. This curve has a minimum, a point at the focal spot size and the exposure time are mutually adjusted to give the least unsharpness or best definition. This means that under the conditions to which this curve is applicable, no possible adjustment of exposure time and focal spot size can give a lesser unsharpness than the minimum value on the curve. The value of minimum unsharpness and of the corresponding exposure time is not affected appreciably by change of target-film distance, but any changes in the other factors, such as speed of film or intensifying screens, the specific load capacity of the focal spot or the speed of movement of the edge of the shadow on the film, will all affect the minimum unsharpness available and the proper adjustment of exposure time and focal spot size to produce minimum unsharpness.

These equations contain the assumption that the specific load capacity of the focal spot does not change with exposure time, whereas, in fact, a focal spot will stand a slightly greater load, in watts per square millimeter, as exposure time is diminished. This would produce a slight decrease in both optimum exposure time and minimum unsharpness, but these effects are so small they can be neglected in the present stage of the investigation.

The exposure time giving the minimum unsharpness, derived from Bouwers' equations, is

$$t_{opt} = \frac{\sqrt[3]{\overline{OF^2}} \cdot E}{\sqrt[3]{4a^2B \cdot \overline{OT^2}}} \qquad (4)$$

and may be called the optimum exposure time. When the total unsharpness is a minimum, it may be shown that

$$U_g = 2U_m \qquad (5)$$

that is, geometric unsharpness is double that due to movement.

The curve U of Figure 3 has a rather broad "valley" where the effect of a small change in exposure time is compensated for almost exactly by the corresponding change required in the focal spot size. The range of times over which total unsharpness is practically unchanged is, in this case, from 0.02 to 0.07 second. It has already been shown that target-film distance has very little effect upon sharpness in chest roentgenograms, and now it is found that within a certain range, exposure time has practically no influence upon the sharpness; both these conclusions result from the conditions that the focal spot is to be used at or near its maximum load carrying capacity. These facts explain why both practical experience and ordinary methods of experimentation have failed to show that any particular target-film distance and exposure time are clearly the best for chest roentgenography.

In general, it is preferable to choose one of the longer exposure times within the permissible range, since this will allow a smaller focal spot to be used, thereby producing better sharpness in the slower moving or stationary positions of the lungs, and diminishing the power required of the roentgen machine. Usually it is found that

the optimum exposure time can be increased 50 per cent without noticeable change in sharpness.

It is of interest to make a few calculations of the optimum exposure time and minimum unsharpness obtainable with representative conditions of chest roentgenography. For the specific load capacity of the focal spot, Bouwers[4] gives the value of 250 watts per square millimeter of area measured on the target face; for a 20-degree target face this value becomes 730 watts per square millimeter of effective area as projected in the direction of the central ray. The conditions assumed, as well as the results obtained, are recorded in Table II.

TABLE II

Given Data	Kilovolts peak	80
	Kilovolts effective	56.6
	Milliampere-seconds	20
	Target-film distance (feet)	6
	Object-film distance (inches)	4
	Anode slope (degrees)	20
	Specific load capacity of focal spot (watts/mm.^{2})	730
	Speed of movement in mm./sec.	5
Calculated Data	Optimum exposure time, t_{opt} (sec.)	0.038
	Milliamperes for t_{opt}	530
	Focal spot width (mm.) for t_{opt}	6.4
	Minimum unsharpness (mm.)	0.57
	$3/2\ t_{opt}$ (sec.)	0.057
	Milliamperes for $3/2\ t_{opt}$	350
	Focal spot width (mm.) for $3/2\ t_{opt}$	5.2
	Total unsharpness for $3/2\ t_{opt}$ (mm.)	0.59

The optimum exposure time comes out practically 1/25 second, the milliamperes required are 530, and the minimum unsharpness is about 0.6 mm. If the optimum exposure time be increased by 50 per cent, to approximately 1/18 second, the unsharpness is not appreciably affected, and the necessary tube current is reduced to about 350 milliamperes.

The following expression for minimum unsharpness may also be derived:

$$U_{min} = \sqrt[3]{\frac{a\,\overline{OF}^2\left(\frac{E}{\overline{OT}^2}\right)}{4B}}. \qquad (6)$$

The discouraging feature of this equation is that minimum unsharpness varies as the cube root of each of the factors under the radical sign, i.e., any material improvements in sharpness will require comparatively large changes in the factors which control sharpness. For instance, if the speed of movement of the lung tissue could be reduced to 1/8 its normal rate, the unsharpness would be reduced to the cube root of 1/8 or to 1/2 the previous unsharpness.

METHODS OF IMPROVING SHARPNESS

Since equation (6) specifies minimum unsharpness in terms of the factors which govern it, it should be profitable to examine this equation to find what factors offer a possibility of material improvement in sharpness. The factor OF, object-film distance, is governed by the size and structure of the patient and is not subject to control. The factor OT, object-target distance, may easily be varied, but the factor E, the energy of the exposure, must be changed with this distance in such a way (in proportion to square of target-film distance) that the ratio $E/\overline{OT}^2$ remains practically constant, and the resultant effect upon sharpness is inappreciable. The factor E may be changed independently of target-film distance by variation in tube voltage, or by a change in the speed of the film or intensifying screens. Unsharpness could be diminished by a reduction in E, but to secure such a reduction by increase of tube voltage would result in lower contrast, so that this possibility is limited in its application. Judging from past experience, a gradual increase in speed of films and intensifying screens may be expected, and the reduction in the energy of the exposure by this means will permit a slight reduction in unsharpness. Since all the fundamental factors affecting sharpness are under the cube root sign, a large change must be made in any of them to influence definition materially; the only factors in which large changes appear possible are a, the velocity of movement of lung tissue, and B, the specific load

capacity of the focal spot. Undoubtedly, the speed of lung tissue movement varies considerably during the heart cycle, and if the roentgenographic exposure can be made at the phase of minimum movement, as suggested by McPhedran and Weyl,[6] an important improvement in sharpness should be obtained.

MOVEMENT OF LUNG TISSUES WITH HEART BEAT

There appears to be no very precise data on the speed of movement of lung tissues in various phases of the heart cycle. Ruggles[7] has used the method of roentgen cinematography for the study of the heart, and his films show the grosser movements in some of the surrounding lung tissue. An examination of his roentgen-ray motion picture on 16 mm. film, "The Heart in Motion," shows that the lung tissues near the heart tend to follow the movements of the heart itself, but lag behind the more rapid heart movements. The greatest lung movement is near the apex of the heart, and the excursion of the lung tissue at this point appears to be about half that of the heart border.

Figure 4 shows the data obtained by Chamberlain and Dock[5] in their analysis of roentgenograms taken by Ruggles' method; the existence of a nodal point is shown on the left border of the heart. The tissues in the left lung also seem to oscillate about this node as a center. The excursion of the tissue movement diminishes from the heart border toward the periphery of the lung. Chamberlain and Dock's plots of the excursions of the heart border at levels 1, 2, and 3 (Fig. 4) make it possible to derive the speed of movement of these points in various portions of the heart cycle. By estimation of the relative movements of the lung tissue and the heart border, it is possible to obtain a rough approximation of speeds of lung movement. Such procedure indicates the speed of lung tissue near the apex of the heart at the time of most rapid

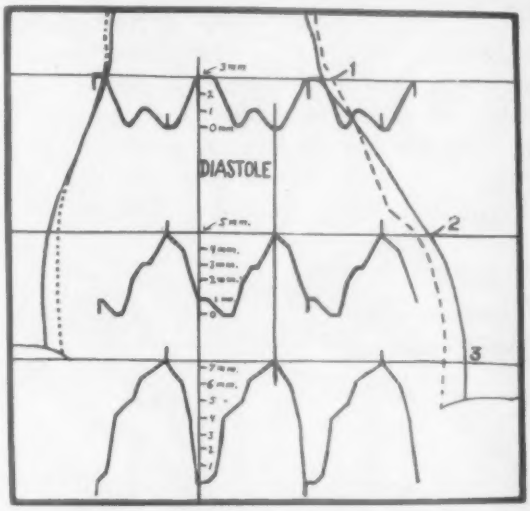

Fig. 4. Chart of heart movement as observed by Chamberlain and Dock.[5] The roentgencardiograms at the points indicated by numbers enable the speed of the heart movement at these points to be determined at various portions of the heart cycle.

Table III

EFFECTS OF VARIOUS SPEEDS OF TISSUE MOVEMENT UPON OPTIMUM EXPOSURE TIME, TUBE CURRENT, AND MINIMUM UNSHARPNESS. THE CONDITIONS 80 KV.P., 20 MA-SEC. 16-DEGREE ANODE SLOPE, 6-FOOT TARGET-FILM DISTANCE, AND 4-INCH OBJECT-FILM DISTANCE, APPLY TO THESE CALCULATIONS.

Speed of Movement in mm. per sec.		20	10	5	2.5	1
For optimum exposure time	Optimum exposure time, $t_{opt.}$	0.014	0.022	0.035	0.056	0.10
	Tube current (ma.)	1440	900	570	360	200
	Focal spot width (mm.)	9.5	7.5	6.0	4.7	3.5
	Minimum unsharpness (mm.)	0.84	0.66	0.53	0.42	0.31
For 3/2 optimum exposure time	Exposure time (sec.)	0.021	0.033	0.053	0.084	0.15
	Tube current (ma.)	950	600	380	240	135
	Focal spot width (mm.)	7.7	6.2	4.8	3.9	2.9
	Unsharpness (mm.)	0.87	0.69	0.56	0.44	0.32

movement to be about 20 millimeters per second. Near the upper left border of the heart the maximum speed of the lung tissue seems to be about 10 to 15 millimeters per second. In the center of the left lung the maximum speed may be estimated at about 5 millimeters per second. These pictures

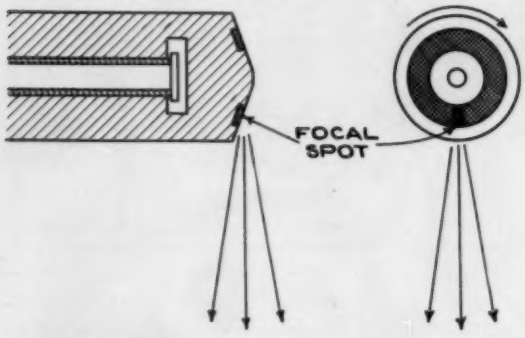

FIG. 5. By means of the rotating target, the effective focal spot can be confined to a small area, while the energy passing through the tube is distributed over the area of a broad ring on the target face.

show very little of the right lung; the movements along the right border of the heart, of course, are less than those on the left.

From an examination of the Ruggles film and of the roentgen cardiograms of Chamberlain and Dock, it seems reasonable to assume that at the most quiescent period of the heart cycle (end of diastole and beginning of systole) the speed of movement of the lung tissue is of the order of 1/8 the maximum speed. In this case calculation shows that the method of McPhedran and Weyl of synchronizing the roentgenographic exposure with the time of minimum movement could be made to reduce the unsharpness by half. At the same time the optimum exposure time is increased four times, and the tube current reduced to 1/4 the original value.

The data of Table III show clearly the advantages of a decrease in speed of tissue movement in improvement of definition and reduction of the tube current required for the exposure. The calculations apply to tissue speeds varying from 20 mm. to 1 mm. per second.

THE REDUCTION OF EFFECTIVE FOCAL SPOT SIZE

Minimum unsharpness can also be decreased by increasing the specific load capacity of the focal spot. One method of doing this is the application of the line focus principle. The apparent area (and form) of the focal spot, as projected upon the film, determines the excellence of the definition afforded, whereas the actual area of the focal spot on the target face determines the energy which can safely be applied within a given exposure time. By suitably reducing the anode slope, or the angle between the target face and the central ray, the effective focal spot size is decreased in proportion to its load capacity. An anode slope of 16 degrees, which, according to Andrus and Hambleton,[8] is permissible at a 6-foot target-film distance, would give a specific load capacity over 2 1/2 times that of a 45-degree anode slope.

Another method of securing a large increase in specific load capacity is to construct the tube so that the anode can rotate on its longitudinal axis;[1] the electron stream from the cathode is focused on an area of the target face some distance away from the center of rotation. The position of the focal spot remains fixed in space, but the rotating target constantly offers a fresh portion of target face to the electron stream, thereby distributing the energy over the area of a broad ring (Fig. 5). According to Bouwers,[3] such a rotating target permits an 8-fold increase in specific load capacity. A rotating line focus target would give $8 \times 2\ 1/2$, or 20 times the specific load capacity of a stationary 45-degree target. According to equation (6), minimum unsharpness would be decreased in the ratio of $\sqrt[3]{20}$ to 1 or to 37 per cent of the minimum unsharpness possible with a stationary 45-degree target.

In Table IV are compared the minimum unsharpness values resulting from the use of a 45-degree anode slope, a 16-degree slope, both on a stationary target, and a 16-degree anode slope on a rotating target, all for a speed of movement of lung tissue

of 20 mm. per second. In addition, the fourth column gives the results of combining the 16-degree stationary target with the synchronization of the exposure with the heart cycle, assuming that under these conditions the speed of movement of lung tissue is reduced to 2.5 mm. per second; the fifth column gives the results of combining a 16-degree rotating target with the lower speed of movement afforded by exposure therefore wise to utilize a method of synchronizing the exposure with the heart cycle along with the use of the rotating target to avoid the necessity for very high tube currents and extremely short exposure times.

If a rotating target tube of reasonable capacity, such as is specified in column 5 of Table IV, is used without the method of exposure synchronization, it will give mini-

TABLE IV

FOR 80 KV.P., 20 MA-SEC. TARGET-FILM DISTANCE OF 6 FEET, AND OBJECT-FILM DISTANCE OF 4 INCHES.

Type of target	1 Stationary	2 Stationary	3 Rotating	4 Stationary	5 Rotating
Anode slope (degrees)	45	16	16	16	16
Effective specific load capacity of focal spot	350	907	7250	907	7250
Speed of movement in mm./sec.	20	20	20	2.5	2.5
Optimum exposure time, t_{opt} (sec.)	0.019	0.014	0.007	0.056	0.028
Milliamperes for t_{opt}	1050	1440	2870	360	714
Effective focal spot width (mm.) for t_{opt}	13.1	9.5	4.7	4.7	2.4
Minimum unsharpness (mm)	1.15	0.84	0.42	0.42	0.21
$3/2\ t_{opt}$ (sec.)	0.029	0.021	0.0104	0.084	0.042
Milliamperes for $3/2\ t_{opt}$	690	952	1920	238	476
Focal spot width (mm.) for t_{opt}	10.6	7.7	3.9	3.9	1.93
Total unsharpness for $3/2\ t_{opt}$ (mm.)	1.20	0.87	0.44	0.44	0.22

synchronization. The conditions 80 kv. p., 20 ma-sec., a target-film distance of 6 feet, and an object-film distance of 4 inches apply to these calculations.

It is apparent that the combination of a rotating line focus target with the reduction of the speed of movement of lung tissue decreases the minimum unsharpness very considerably; and unsharpness of only 0.2 mm. in a roentgenographic image may be considered very satisfactory and would represent a marked improvement in sharpness over that of chest techniques now in common use.

The data in Table IV also show that increase of specific load capacity of the focal spot makes a shorter exposure time and a higher tube current necessary to obtain minimum unsharpness, whereas reduction of speed of movement permits a longer exposure with a lower tube current. It is mum unsharpness only in the more slowly moving portions of the lungs, but will fail to give the best sharpness in the more rapidly moving portions near the heart. Without exposure synchronization, the wide variation in speed of lung tissues over the whole lung field make it impossible to secure the best sharpness of every portion of the lungs with a single exposure. Shorter exposures, with the correspondingly larger focal spots, will improve definition in the more rapidly moving portions of the lungs, but will decrease the sharpness in the stationary and more slowly moving tissues, whereas the longer exposures, with smaller focal spots, will favor the more slowly moving tissues in the matter of sharpness, at the expense of sharpness in the rapidly moving portions. If, however, the exposure can be synchronized with the phase of minimum movement of the lungs, the speed varia-

tions of the different portions will be greatly reduced, and a more uniform sharpness can be secured over the whole lung field.

The energy, in watt seconds, required for a chest exposure depends upon tube voltage. Since, according to equation (6), minimum unsharpness depends upon the energy of the exposure, it will also be affected by the value of the voltage applied to the roentgen tube during the exposure. Assuming that the number of milliampere-seconds necessary for a chest roentgenogram varies inversely as the cube of the tube voltage, it is possible to calculate the extent to which minimum unsharpness is influenced by the voltage. Table v gives the results obtained for three values of kilovoltage, with a 16-degree stationary target and a lung tissue speed of 20 mm. per second. Table vi gives similar data for a lung tissue speed of 5 mm. per second. It is apparent that a decrease in tube voltage produces a relatively small increase in unsharpness. The increased contrast at the lower kilovoltages may partially, perhaps wholly, compensate for the calculated increase in unsharpness, since it is generally true that increase of contrast improves apparent sharpness to some extent. In any case the effect upon sharpness need not be seriously considered in the choice of tube voltage.

TABLE V

EFFECT OF TUBE VOLTAGE ON MINIMUM UNSHARPNESS, FOR 16-DEGREE ANODE SLOPE, STATIONARY TARGET, LUNG TISSUE SPEED OF 20 MM. PER SEC., A TARGET-FILM DISTANCE OF 6 FEET, AND AN OBJECT-FILM DISTANCE OF 5 INCHES.

Kv.p.	60	80	100
Optimum exposure time, t_{opt} (sec.)	0.017	0.014	0.012
Milliamperes for t_{opt}	2800	1440	850
Effective focal spot width (mm.) for t_{opt}	13.0	9.5	8.1
Minimum unsharpness (mm.)	1.01	0.84	0.72
$3/2\ t_{opt}$ (sec.)	0.025	0.021	0.018
Milliamperes for $3/2\ t_{opt}$	1895	950	567
Focal spot width (mm.) for t_{opt}	9.4	7.7	6.6
Total unsharpness for $3/2\ t_{opt}$ (mm.)	1.05	0.87	0.75

Table v also shows that to obtain the best definition in the more rapidly moving portions of the lungs, the tube current with a line focus tube should be in the neighborhood of 1,000 to 3,000 milliamperes at the voltages most commonly used. The greater portion of the lung area, however, probably does not move faster than 5 mm. per second, and if exposures are designed to give the best definition at such a speed, longer exposure times and less power may be used, as shown by the data of Table vi. It seems reasonable, therefore, with the roentgen-ray equipment now available, to attempt to secure the best definition only in those portions of the lungs which are moving less than 5 mm. per second—portions which constitute the greater part of the lung area. Assuming that the exposure time may be 50 per cent greater than the optimum time, such roentgenograms may be obtained with exposures of approximately 1/20 second at 400 ma. at 80 kv. p. and a 6-foot target-film distance. Under these conditions the unsharpness is approximately 0.6 mm.

TABLE VI

CALCULATIONS FOR 16-DEGREE ANODE SLOPE, STATIONARY TARGET, LUNG TISSUE SPEED OF 5 MM. PER SEC., A TARGET-FILM DISTANCE OF 6 FEET, AND AN OBJECT-FILM DISTANCE OF 4 INCHES.

Kv.p.	60	80	100
Optimum exposure time, t_{opt} (sec.)	0.042	0.035	0.030
Milliamperes for t_{opt}	1150	570	338
Effective focal spot width (mm.) for t_{opt}	7.2	6.0	5.1
Minimum unsharpness (mm.)	0.64	0.53	0.45
$3/2\ t_{opt}$ (sec.)	0.064	0.053	0.045
Milliamperes for $3/2\ t_{opt}$	740	378	227
Focal spot width (mm.) for t_{opt}	5.9	4.8	4.2
Total unsharpness for $3/2\ t_{opt}$ (mm.)	0.67	0.56	0.47

If the contrast provided by 60 kv.p. is desired, the tube current must be nearly 800 ma., and the unsharpness for a 5 mm. per second lung tissue speed increases to about 0.7 mm. If the target-film distance is reduced to 4 feet, the above milliampere values may be cut in half, with little or no appreciable loss in definition. If definition is to be further improved and the best definition is to be obtained in the faster moving portions of the lungs, the exposure should be synchronized with the phase of minimum movement of the lung tissues and a rotating target tube should be used.

In all the above calculations an object-film distance of 4 inches was used. This was chosen because it probably represents the distance at which the heart produces the maximum movement in the adjacent lung tissue. The exposure time chosen in each case was 50 per cent greater than the optimum exposure time. Such an exposure time gives practically as good definition as the optimum time, permits a one-third reduction in the power required for the exposure, and makes possible a smaller focal spot. The smaller focal spot, in turn, improves the definition in the portions of the lungs farther from the film and in the portions which move more slowly. Therefore, the procedure of applying the Bouwers equation to the object-film distance at which lung movement is most rapid, and increasing the resulting optimum exposure time by 50 per cent, leads to exposure conditions which tend to give the best average definition over the whole lung field.

In all cases, the selection of an exposure time 50 per cent greater than the optimum time was found to make movement unsharpness about equal to geometric unsharpness. In other words, the best all-round balance between movement unsharpness and geometric unsharpness occurs when both are nearly the same. There is little use in attempting to improve definition in chest roentgenography by shortening the exposure time without also taking steps that will enable a smaller focal spot to withstand the greater power input.

EXPOSURE CONDITIONS FOR AVAILABLE EQUIPMENT

The above considerations indicate the methods affording the best prospects of improvement of sharpness. At the present time, however, all the facilities for achieving these improvements are not generally available. Hence the question is, what exposure conditions should be chosen with existing limitations of equipment to secure the best all-round definition in chest roentgenograms?

Line focus tubes are commonly manufac-

TABLE VII

FOR STATIONARY TARGET OF 20-DEGREE ANODE SLOPE, LUNG TISSUE SPEED OF 5 MM. PER SEC., TARGET-FILM DISTANCE OF 6 FEET, AND OBJECT-FILM DISTANCE OF 4 INCHES.

Kv.p.	1 60	2 70	3 80	4 90	5 100
Milliampere-seconds	47.4	29.8	20	14	10.2
Specific load capacity of focal spot	730	730	730	730	730
Optimum exposure time (sec.) t_{opt}	0.046	0.041	0.038	0.035	0.032
Milliamperes for t_{opt}	1030	725	530	400	320
Focal spot width (mm.) for t_{opt}	7.7	7.0	6.4	5.9	5.6
Minimum unsharpness (mm.)	0.69	0.62	0.57	0.52	0.49
$3/2\ t_{opt}$ (sec.)	0.069	0.062	0.057	0.052	0.049
Milliamperes for $3/2\ t_{opt}$	690	480	350	270	210
Focal spot width (mm.) for t_{opt}	6.3	5.7	5.2	4.8	4.5
Total unsharpness for $3/2\ t_{opt}$	0.72	0.65	0.59	0.54	0.51

tured with an anode slope of about 20 degrees. In the absence of equipment for synchronizing exposures with the heart cycle, it does not seem desirable to attempt to secure the best possible definition in the more rapidly moving portions of the lungs, but rather to compromise by securing the best definition over the greater portion of the lung area, where the speed of movement apparently does not exceed 5 mm. per second.

TABLE VIII

THE CONDITIONS 80 KV.P., 20 MA-SEC., 20-DEGREE ANODE SLOPE, 6-FOOT TARGET-FILM DISTANCE, AND 4-INCH OBJECT-FILM DISTANCE, APPLY TO THESE CALCULATIONS.

	Stationary Target	Rotating Target
Specific load capacity of focal spot	730	5840
Speed of movement in mm./sec.	5	5
Optimum exposure time (sec.) t_{opt}	0.038	0.019
Milliamperes for t_{opt}	530	1060
Focal spot width (mm.) for t_{opt}	6.4	3.2
Minimum unsharpness (mm.)	0.57	0.28
$3/2\ t_{opt}$ (sec.)	0.057	0.028
Milliamperes for $3/2\ t_{opt}$	350	715
Focal spot width (mm.) for $3/2\ t_{opt}$	5.2	2.6
Total unsharpness for $3/2\ t_{opt}$ (mm.)	0.59	0.30

The calculations in Table VII are made for a 6-foot target-film distance, but the data for other distances may be readily derived from the tabulated values by making focal spot width proportional to target-film distance and tube current proportional to the square of target-film distance; exposure time should not be changed with target-film distance. The calculations for Table VII are for a stationary target of 20 degrees' anode slope, lung tissue speed of 5 mm. per second, target-film distance of 6 feet, and object-film distance of 4 inches.

Under these conditions, the recommended exposure times vary from 1/20 to 1/14 second, the tube current from 200 to 700 ma., while resultant unsharpness values vary from 0.5 to 0.7 mm., depending on the tube voltage chosen. Sharpness is affected but little by tube voltage, so that the choice of voltage is governed largely by the preference as regards contrast, subject to the limitations in power of the roentgen-ray generating apparatus.

Using shorter exposure times than those of Table VII would produce better definition in the more rapidly moving portions of the lungs, at the sacrifice of definition in the slower portions, and would be desirable only in case it is desired to secure improved sharpness in the lung tissues nearest the heart.

Suppose that the output of the roentgen machine is limited to 100 ma. at the customary roentgenographic voltages. What would be the best chest technique with such a machine? The target-film distance may be reduced to 4 feet with no appreciable loss of definition *as long as the focal spot width is reduced in the same proportion*. The distortion in the single roentgenogram will be increased slightly at the shorter distance whereas the distortion in the stereoscopic image will be lessened. With these changes, adequate exposure for most chests will be given by 80 kv.p., 90 ma., and 1/10 second. Under these conditions, the unsharpness for a lung tissue speed of 5 mm. per second, with a line focus tube, would be 0.74 mm., which is only slightly greater than that given by the conditions recommended for 80 kv.p. in Table VII.

The calculations for rotating target with 20-degree anode slope, a lung tissue speed of 5 mm. per second, 80 kv.p., 6-foot target-film distance, and 4-inch object-film distance in comparison with calculations for a stationary 20-degree target, are recorded in Table VIII. A rotating target tube similar to that specified in this table, but with focal spot 2 mm. in width should be used at a shorter distance, about 4 feet, and the tube current reduced to about 300 ma.

It is of interest to examine the changes in sharpness produced by the successive application of the various factors which im-

prove sharpness, starting with a stationary 45-degree target face, a roentgen machine limited to 100 ma., and an exposure time of 1/10 second, and proceeding, in turn, to a stationary line focus tube, then an increase in the power of the roentgen machine (100 ma. limit removed), an increase of target-film distance from 4 to 6 feet, next the use of a rotating target tube, and, finally, the synchronization of the exposure with the heart cycle. In Table IX, the values

TABLE IX

	Stationary Target				Rotating Target	Rotating Target
						Exposure synchronized with heart cycle
Speed of tissue movement (mm./sec.)	5	5	5	5	5	0.62
Anode slope (degrees)	45	20	20	20	20	20
Milliamperes	90	90	154	350	715	180
Kilovolts peak	80	80	80	80	80	80
Target film distance (feet)	4	4	4	6	6	6
Exposure time (sec.)	0.10	0.10	0.058	0.057	0.028	0.113
Unsharpness (mm.)	0.84	0.74	0.60	0.59	0.30	0.15
Percentage reduction in unsharpness		12	19	2	49	50

of total unsharpness produced by these successive changes in technique are calculated for a tube voltage of 80 kv.p. and a speed of lung tissue movement of 5 mm. per second, except in the last computation, where the synchronization is assumed to reduce the speed of movement to 1/8 of 5 mm. or 0.62 mm. per second. After the removal of the 100 ma. limit on the roentgen machine, the target-film distance is increased to 6 feet, the exposure times selected are 50 per cent greater than the optimum time, and the tube currents are those necessary to give adequate exposure in this time. An object-film distance of 4 inches is assumed throughout.

It is apparent from these calculations that the greatest improvements in sharpness are produced by use of the rotating target tube and the synchronization of the exposure with the heart cycle. Increase of target-film distance from 4 to 6 feet produces no perceptible improvement in sharpness, while the change from a 45-degree to a 20-degree anode slope, and any decrease in exposure time below 1/10 second produce relatively small reductions in total unsharpness.

With the method of exposure synchronization, the exposure technique and focal spot size can be designed to secure the best sharpness in the more rapidly moving portions of the lungs without noticeable sacrifice of sharpness in the more slowly moving portions. The specifications of column 5 of Table IV appear, therefore, better suited for roentgenography of the whole lung field than those of the last column of Table IX.

GENERAL CONSIDERATIONS

Bouwers[3] has pointed out that the reduction in exposure made possible by intensifying screens acts to give better definition in chest roentgenography than would be obtained without the use of screens. Under typical conditions of chest roentgenography, intensifying screens reduce exposure by a factor of about 16.* If a chest roentgenogram were made without intensifying screens, the 16-fold increase in exposure would, according to equation (6), multiply

* The intensifying factor may vary considerably, depending upon the hardness of the radiation used for the exposure.

the minimum unsharpness by a factor equal to $\sqrt[3]{16}$ or 2.5. An unsharpness 0.6 mm. obtained with these screens would be increased to 1.5 mm., if the exposure were made on plain roentgen film.

Since the unsharpness obtainable in chest roentgenograms under ordinary conditions is 0.5 mm. or more, the limitations of intensifying screen unsharpness are not particularly important. If an unsharpness of 0.2 mm. or less can be obtained by the use of rotating target tube combined with exposure synchronization, the requirements as regards the definition characteristics of intensifying screens must be more severe.

The quantitative results on exposure times and unsharpness values are based on speeds of lung movement which are known with only a rough degree of approximation. These values of exposure times are doubtless sufficiently reliable for use in routine chest roentgenography with apparatus now in common use. The conclusions from Bouwers' method of analysis regarding the importance of the rotating target tube, and the synchronization of the exposure with the phase of minimum movement of the lung tissue, are valid regardless of the accuracy of the data on speed of lung tissue movement.

To effect future improvements in chest roentgenography, particularly in connection with the method of exposure synchronization, more accurate and more detailed data on lung tissue movements are desirable, such as could be obtained by Ruggles' method of roentgen cinematography. With such data, the results of Bouwers' method of analysis could be obtained with greater precision, and, furthermore, reliable information on the variations in tissue speed in different portions of the lungs and in various pathological conditions would provide a rational basis for the adaptation of exposure technique to secure the best definition in each individual case, as governed by the speed of movement of the area of principal interest.

SUMMARY

The sharpness of outline of roentgen shadows of the lung tissues is governed chiefly by two factors, the movement of the tissues with the heart beat, and the size of the focal spot of the roentgen tube. The mutual adjustment of these factors to produce the best resultant sharpness may be worked out by the analytical method of Bouwers. The application of this method to chest roentgenography indicates that, in the main, the exposure times giving the best definition or sharpness of lung tissue are in the neighborhood of 1/20 second. The analysis also shows that the best prospects for marked improvement in sharpness lie in the use of a rotating target line focus roentgen tube, and in the synchronization of the exposure with the phase of minimum lung movement, as proposed by McPhedran and Weyl. The latter procedure has the additional merits of permitting longer exposure times, decreasing the power required of the roentgen machine, and minimizing the distortion in the stereoscopic image caused by movement of the lung tissues between stereoscopic exposures.

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THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

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American Congress of Radiology†*

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Committee on Scientific Program

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Chairman: Henry Schmitz, 25 East Washington St., Chicago, Ill.

Committee on Membership

Chairman: Albert Soiland, 1407 South Hope St., Los Angeles, Calif.

Headquarters of the Executive Council: 2561 North Clark St., Chicago, Ill.

For Program of American Congress of Radiology: See August issue, page 250.

Date of Meeting: September 25–30, 1933.

Place of Meeting: Palmer House, Chicago Ill., Scientific Sessions, Scientific and Commercial Exhibits will all be held in this Hotel.

* For Officers and Standing Committees of the American Roentgen Ray Society and the American Radium Society usually carried on this page, see the April, 1933, number of the Journal.

† Combined meeting of: American Roentgen Ray Society, American Radium Society, American College of Radiology, Radiological Society of North America.

EDITORIALS

INTRAVENOUS UROGRAPHY IN CHILDREN

THE simplification of any method of examination which at the same time obviates the dangers of the examination is always to be sought for in medical practice. Thus the introduction of intravenous pyelography opened up a new field for the study of genitourinary diseases in children. While the cystoscopic examination in association with retrograde pyeloscopy and pyelography in the adult offered one of the greatest advances in diagnostic procedures, this method of examination in children is always fraught with a certain amount of difficulty, both on account of the reactions which are encountered in children, and because of the necessity of employing general anesthesia. Yet there is perhaps no more frequent examination indicated in children than a study of the genitourinary system. That the intravenous method is not as generally employed in children as it should be is evident by the relatively few reports in the literature, though recent reports of Teall,[1] of Schwentker[2] and of Campbell[3] emphasize the importance of this method.

Teall emphasizes its importance by noting the fact that at the Children's Hospital in Birmingham, England, in the two years from 1928 to 1930, only six retrograde pyelographic examinations were made, while during the last two years fifty patients have been investigated by the intravenous method. The simplicity of the technique of the intravenous method of urography in children is sufficient to justify its widespread use, and with the introduction of some of the more recent Bucky grids where the leads are so thin that the faint lines of the grid do not interfere with the diagnostic value of the films the operator is able to shorten the exposure and thereby obtain a more clear cut detailed roentgenogram of the urinary tract.

That the intravenous method of urography in children is definitely satisfactory for diagnosis has been emphasized by Schwentker who made a comparison of the intravenous with the retrograde method. He came to the conclusion that in no instance was the diagnosis made by one method where it could not have been derived independently by the other, and that the results obtained by either route are not always satisfactory at the first attempt. Undoubtedly the simplicity of the intravenous method of urography in children offers an advantage over the retrograde method and its employment should be more widespread than is generally the case.

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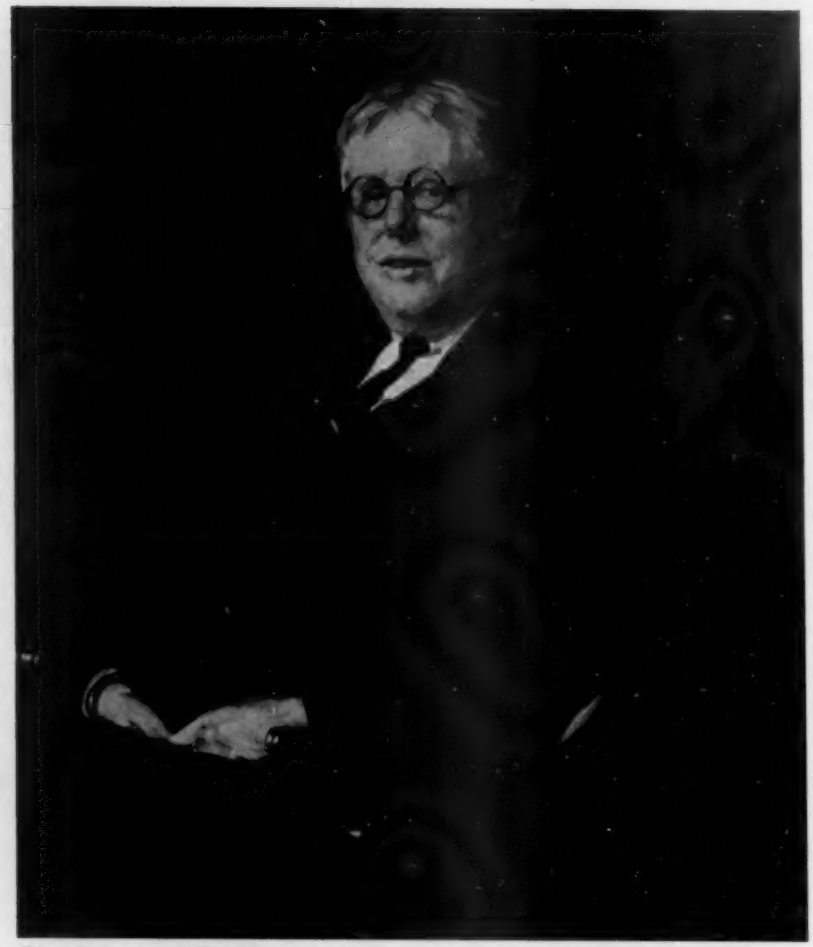

From the painting by Eric Haupt, 1931

FREDERICK H. BAETJER

FREDERICK HENRY BAETJER
1874 - 1933

MEMBERS of the American Roentgen Ray Society who attended the Baltimore meeting of 1905 at the Johns Hopkins Hospital will recall to mind without difficulty the active and seemingly omnipresent figure of a gentleman of affable mien and soft speech, as solicitous for the comfort and pleasure of his guests as if, instead, we had been gathered beneath the roof of his ancestral home. Those of us who had not known him previously soon learned that our gracious host was Baetjer—a name ultimately to adorn his profession; a name soon to be heard upon the lips and found within the hearts of his colleagues at home and abroad; a name that now becomes, as a result of courageous persistence, of high purpose and of self totally ignored in the face of another's need, a cherished memory.

Frederick Henry Baetjer was born in Baltimore in 1874, the son of Henry and Frederika (Cronhardt) Baetjer, and died on July 17, 1933. Shortly after his birth his parents removed to Winchester, Virginia, where were passed his young boyhood days. His school-life at the Shenandoah Academy terminated with his entrance to the Johns Hopkins University, where he received the Bachelor's degree in Arts with the class of 1897. He was graduated with the Doctor's degree from the Johns Hopkins Medical School in 1901. In 1903 he married Mary Yarnall Carey, who, with two children, survives him. But eight hours after Baetjer's death a grandchild was born, upon whom rests the honor of bearing his name.

Most interesting is the origin of Doctor Baetjer's devotion to the medical application of x-rays. In the early days of roentgenologic activity at Johns Hopkins, it was customary for the work to be assigned in rotation to one of the house-officers. In due course, this duty fell to Baetjer and thus, in "looking after the x-ray room," was his enthusiastic interest engendered and his career moulded. Much of the year 1902 was spent in the laboratories of Albers-Schönberg and Immelmann in Hamburg and Berlin. At Johns Hopkins, as elsewhere, the need of a special department for x-ray work was becoming urgent, and on Baetjer's return from abroad he was appointed "Actinographer" to the Hospital, a titular definition not altogether relished by him, but not to be changed until 1915, when the nomenclature now obtaining in this country was formally adopted. He was successively appointed Assistant, Instructor, Associate and Associate Professor, becoming Professor of Roentgenology in 1921.

Doctor Baetjer took a major part in the development of the American Roentgen Ray Society, with which he was prominently connected for so many years. Especially did he cherish the personal contacts it afforded and the friendships that grew out of it; his annual opportunities to renew these associations were curtailed only by recurrences of ill health in him or in his family. His hand was strong in the direction of the policies of the Society, into which he instilled the spirit of his high idealism, thus promoting from concept to principle the now-formulated rule that the practice of roentgenology is based on the expression of opinion evolved from scientific investigation, instead of being a more or less glorified manifestation of the techniques of the photographer's art. Doctor Baetjer was elected President of the Society in 1911 and was its Caldwell Lecturer for the year 1929.

Baetjer's record of service in the World War was notably distinguished. At first, as a Major of the Medical Corps of the Army, he conducted in Baltimore one of the temporary schools of Military Roentgenology;

later he was ordered to the large New York school as Instructor. This post he occupied until all schools were combined at Camp Greenleaf, Fort Oglethorpe, Georgia.

The fabric of his pedagogic methods, especially successful in his University work, was strengthened by the intertexture of his personal charm. He became generally known as a great teacher. In illustration of this was his almost uncanny ability correctly to interpret the objective data of roentgenogram or screen, and it was his joy and delight to deduce and to reconstruct therefrom the *clinical* picture of the case, to the fascination of his colleagues and the inspiration of his students. Aside from his routine teaching, Doctor Baetjer contributed notably to the literature; he did early and important work on thoracic aortic aneurysm and was a pioneer authority on the roentgen-pathology of the bones and joints.

At commemoration exercises held at the Johns Hopkins Hospital in February, 1932, the late Dr. William Sydney Thayer, in presenting to the University a portrait of Doctor Baetjer, said of him:

"Who is more universally loved than Baetjer? A singularly alert and engaging figure, interested in clinical medicine and surgery, he was one of the earliest to devote himself to the applications of the then new roentgenolgical diagnosis. . . . Endowed by nature with an unusually acute, lucid, logical mind . . . he has become a diagnostician of rare ability, a recognized leader and an unsurpassed teacher in his especial field. . . .

"These diagnostic conferences of Baetjer's are impressive—I had almost said incomparable—demonstrations of the power of acute observation, of orderly, logical reasoning, of sound deduction; they are an inspiration alike to student and colleague."

* * * *

Baetjer's personality radiated an aura of such good cheer, even joviality, that it was difficult to detect beneath it any trace of the momentary vexation that might well assail an ardently enthusiastic spirit under the restraint of physical handicaps. His fortitude made him appear blind to the causes and effects of the operative procedures—totalling over one hundred—that his injuries entailed. Within his visual fields there was only the race to be run over a course of his own plotting, and the tape to be breasted.

His colleagues the world over need no editorial eulogy to deepen their insight into this man's character and life. For them, its strength and its accomplishment are written in terms of hindrances overcome, resistances thrust aside, hazards scorned. In its record they see the allegiance to duty, to ideals and to purpose inherent in the fibre of an American gentleman, physician and soldier consecrated to a life of devotion within the cloisters of his beloved University. As she contemplates her service to Humanity through the mediumship of his loyalty and skill, she may well and pridefully perpetuate the memory of one of the greatest of her great Alumni.

PERCY BROWN

SOCIETY PROCEEDINGS CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

United States of America

American Roentgen Ray Society
Secretary, Dr. E. P. Pendergrass, University Hospital, Philadelphia, Pa.
Annual Meeting: Chicago, Ill., Sept. 25–30, 1933.

American College of Radiology
Secretary, Dr. Albert Soiland, 1407 S. Hope St., Los Angeles, Calif.
Annual meeting: Chicago, Ill., Sept. 25–30, 1933.

Section on Radiology, American Medical Association
Secretary, Dr. J. T. Murphy, 421 Michigan St., Toledo, Ohio.
Annual meeting: Cleveland, Ohio, June 11–15, 1934.

Radiological Society of North America
Secretary, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y.
Annual meeting: Chicago, Ill., Sept. 25–30, 1933.

Radiological Section, Los Angeles County Medical Society
Secretary, Dr. R. T. Taylor, Los Angeles, Calif.
Meets on the third Wednesday of each month at the California Hospital.

Radiological Section, Southern Medical Association
Secretary, Dr. C. H. Heacock, 20 S. Dunlap St., Memphis, Tenn.
Annual meeting: Richmond, Va., November, 1933.

Brooklyn Roentgen Ray Society
Secretary, Dr. G. W. Cramp, 921 President St., Brooklyn, N. Y.
Meets monthly on first Tuesday, October to April.

Buffalo Radiological Society
Secretary-Treasurer, Dr. Joseph S. Gian-Franceschi, 610 Niagara St., Buffalo, N. Y.
Meets second Monday of each month except during summer months, place of meeting selected by the host.

Chicago Roentgen Society
Secretary, Dr. R. G. Willy, 1138 N. Leavitt.
Meets second Thursday of each month October to May inclusive at the Palmer House.

Cincinnati Radiological Society
Secretary, Dr. H. G. Reineke, Christian R. Holmes Hospital, Cincinnati, Ohio. Meetings held monthly.

Cleveland Radiological Society
Secretary, Dr. Otto Glasser, Cleveland Clinic.
Meetings are held at 6:30 P.M. at the Cleveland Chamber of Commerce Club rooms on the fourth Monday of each month from October to April, inclusive.

Detroit Roentgen Ray and Radium Society
Secretary, Dr. E. R. Witwer, Harper Hospital.
Meets monthly on first Thursday from October to May, at Wayne Country Medical Society Building.

Florida Radiological Society
Secretary, Dr. W. McL. Shaw, 418 St. James Bldg., Jacksonville, Fla.
Meetings held twice a year, May and November.

Illinois Radiological Society
Secretary, Dr. H. W. Grote, 219 N. Main St., Bloomington, Ill.
Regular meetings held quarterly.

Indiana Roentgen Society
Secretary, Dr. J. N. Collins, Indianapolis, Ind.
Annual meeting each February 22 in Indianapolis.

Michigan Association of Roentgenologists
Secretary, Dr. S. W. Donaldson, St. Joseph's Mercy Hospital, Ann Arbor, Mich. Three meetings a year, Fall, Winter, and Spring. Next meeting, Kalamazoo, Mich., October, 1933.

Milwaukee Roentgen Ray Society
Secretary, Dr. J. E. Habbe, 221 Wisconsin Ave., Milwaukee, Wis.
Meets first Friday in October, December, February and April. Place of meeting designated by the president.

Minnesota Radiological Society
Secretary, Dr. L. G. Rigler, University Hospital, Minneapolis, Minn.

New England Roentgen Ray Society
Secretary, Dr. Thomas R. Healy, 370 Marlboro St., Boston, Mass.
Meets monthly on third Friday, Boston Medical Library.

New York Roentgen Society
Secretary, Dr. C. W. Schwartz, 33 E. 68th St., New York.
Meets monthly on third Monday, New York Academy of Medicine, at 8:30 P.M.

North Carolina Roentgen Ray Society
Secretary, Dr. Major Fleming, Rocky Mount, N.C.
Annual meeting at time and place of State Medical Society. Mid-year scientific meeting at place designated.

Central New York Roentgen Ray Society
Secretary, Dr. H. S. Bull, 604 Masonic Temple, Auburn, N. Y.
Three meetings a year—January, May and November.

Pennsylvania Radiological Society
Secretary, Dr. W. E. Reiley, Clearfield, Penna.

Philadelphia Roentgen Ray Society
Secretary, Dr. Karl Kornblum, Graduate Hospital.
Meeting first Thursday of each month from October to May inclusive, at 8:15 P.M., in Thompson Hall, College of Physicians, 19 S. 22d St.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. W. W. Fray, Strong Memorial Hospital.
Meets monthly on second Thursday from October, 1932, to May, 1933 inclusive, at 7:45 at the Rochester Medical Association Building.

St. Louis Roentgen Club
Secretary, Dr. W. K. Mueller, University Club Bldg.
Meets first week of each month. Time and place of meetings designated by president.

South Carolina X-Ray Society
Secretary, Dr. R. B. Taft, 105 Rutledge Ave., Charleston.
Meets at time and place of South Carolina State Medical Association.

Texas Radiological Society
Secretary-Treasurer, Dr. C. P. Harris, Houston, Texas.
Meets annually one day preceding the meeting of the Texas State Medical Association.

University of Michigan Roentgen Ray Society
Secretary, Dr. C. C. Taylor, University Hospital, Ann Arbor, Mich.

* Secretaries of Societies not here listed are requested to send the necessary information to the Editor.

Meets first and third Wednesday evening of the month from October to June, at 8 o'clock in the amphitheatre of the University Hospital.

VIRGINIA ROENTGEN RAY CLUB
Secretary, Dr. Wright Clarkson, 205 S. Sycamore St., Petersburg, Va.
Meets annually in October.

CUBA

SOCIEDAD CUBANA DE RADIOLOGIA Y FISIOTERAPIA
Secretary, Dr. Luis Fariñas, Animas 110, Havana, Cuba.
Meets monthly in Havana.

BRITISH EMPIRE

BRITISH INSTITUTE OF RADIOLOGY INCORPORATED WITH THE RÖNTGEN SOCIETY
Meets on the third Thursday of each month, from November to June inclusive, at 8:15 P.M., at 32 Welbeck St., London, W. 1., or as advertised.

ELECTRO-THERAPEUTIC SECTION OF THE ROYAL SOCIETY OF MEDICINE (CONFINED TO MEDICAL MEMBERS)
Meets on the third Friday of each month during the winter at 8:30 P.M. at the Royal Society of Medicine, 1 Wimpole St., London, W. 1.

SECTION OF RADIOLOGY AND MEDICAL ELECTRICITY, AUSTRALASIAN MEDICAL CONGRESS
Secretary, Dr. H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

RADIOLOGICAL SECTION OF THE VICTORIAN BRANCH OF THE BRITISH MEDICAL ASSOCIATION
Secretary, Dr. Colin Macdonald, Lister House, 61 Collins St., Melbourne, Australia.
Meets monthly at Melbourne during the winter.

SECTION ON RADIOLOGY, CANADIAN MEDICAL ASSOCIATION
Secretary, Dr. A. H. Rolph, 160 St. George St., Toronto, Ont.

INDIAN RADIOLOGICAL ASSOCIATION
Secretary, Sd. Subodh Mitra, 148 Russa Rd., Calcutta.
Meets annually in January, and at such places and times as the Council may appoint.

RADIOLOGICAL SECTION, NEW ZEALAND BRITISH MEDICAL ASSOCIATION
Secretary, Dr. P. C. Fenwick, The Hospital, Christchurch. Meets annually.

CONTINENTAL EUROPE

BELGIAN SOCIETY OF ROENTGENOLOGY
Secretary, Dr. J. Boine, Avenue des Allies, 134, Louvain, (Belgian).
Meets monthly on second Sunday at d'Egmonds Palace, Brussels, except in the summer time.

SOCIÉTÉ DE RADIOLOGIE MÉDICALE DE FRANCE
Meets monthly on second Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

SOCIÉTÉ SUISSE DE RADIOLOGIE (SCHWEIZERISCHE RÖNTGEN-GESELLSCHAFT)
Secretary for French language, Dr. A. Grosjean, La Chaux de Fonds.
Secretary for German language, Dr. Scheurer, Molzgasse, Biel.
Meets annually in different cities.

SOCIÉTÉ FRANCAISE D'ELECTROTHÉRAPIE ET DE RADIOLOGIE MÉDICALE
Meets monthly on fourth Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

ASSOCIATION OF GERMAN ROENTGENOLOGISTS AND RADIOLOGISTS IN CZECHO-SLOVAKIA
Secretary, Dr. Walter Altschul, German University, Prague, 11/52.

DEUTSCHE RÖNTGEN-GESELLSCHAFT (GESELLSCHAFT FÜR RÖNTGENKUNDE UND STRAHLENFORSCHUNG)
Meets annually in April in different German cities, at least once in five years in Berlin. Meets in addition every two years with the Gesellschaft deutscher Naturforscher und Aerzte.
Permanent secretary, Professor Dr. Haenisch, Klopstockstrasse 10, Hamburg, Germany.

DUTCH SOCIETY OF ELECTROLOGY AND ROENTGENOLOGY
Holds two meetings a year in Amsterdam, one in the Spring, and one in the Fall.

SOCIETA ITALIANA RADIOLOGIA MEDICA
Secretary, Professor M. Ponzio, University of Turin, Turin.

SOCIETATEA ROMANA DE RADIOLOGIE SI ELECTROLOGIE
Secretary, Dr. Oscar Meller, Str. Banul Maracine 30 Bucarest, Rumania.
Meets second Monday in every month with the exception of July and August.

ALL-RUSSIAN ROENTGEN RAY ASSOCIATION, LENINGRAD, USSR, in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson.
Meets annually.

LENINGRAD ROENTGEN RAY SOCIETY
Secretaries, Drs. S. G. Simonson and G. A. Gusterin.
Meets monthly, first Monday at 8 o'clock, State Institute of Roentgenology and Radiology, Leningrad.

MOSCOW ROENTGEN RAY SOCIETY.
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky.
Meets monthly on the first Monday at 8 o'clock, the place of meeting being selected by the Society.

POLISH SOCIETY OF RADIOLOGY
Secretary, Dr. Jan. Kochanowski, 45 Gornoslazka St., Warsaw. Meets annually.

WARSAW SECTION, POLISH SOCIETY OF RADIOLOGY
Secretary, Dr. B. Krynski, 11 Zielna St.
Meets once a month except in the summer time.

SCANDINAVIAN ROENTGEN SOCIETIES
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association. Each of the following societies, with exception of the Denmark Society, meets every second month except in the summer time.

SOCIETY OF MEDICAL RADIOLOGY OF SWEDEN
Meets in Stockholm.

SOCIETY OF MEDICAL RADIOLOGY IN NORWAY
Meets in Oslo.

SOCIETY OF MEDICAL RADIOLOGY IN DENMARK
Secretary, Dr. H. Scheuermann, Copenhagen.
Meets on the second Wednesday of each month from October to July in Copenhagen, at 8 o'clock in the State Institute of Roentgenology.

SOCIETY OF MEDICAL RADIOLOGY IN FINLAND
Meets in Helsingfors.

VIENNA SOCIETY OF ROENTGENOLOGY
Meets first Tuesday each month, October to July.

ORIENT

JAPAN X-RAY ASSOCIATION
c/o Orthopedic Surgery, Tokyo Imperial University.
Meets annually in April.

KINKI ROENTGEN-ABEND SOCIETY
Director, Dr. Prof. Taiga Saito, Ogawaoike, Kyoto, Japan. Meets bi-monthly on third Sunday.

EXHIBIT OF PICTORIAL PHOTOGRAPHY

In the January (1933) number of the American Journal of Roentgenology and Radium Therapy there appeared a letter, written by Dr. A. U. Desjardins, Rochester, Minnesota, in which he attracted attention to the fact that, next to physics and electrical engineering, knowledge of photography is the most valuable asset to the roentgenologist, and in which he stressed the desirability of photography as a hobby. Many members of the American College of Radiology, the American Roentgen Ray Society, the Radiological Society of North America, and the American Radium Society have long been interested in photography, and the interest of those who practice diagnostic roentgenology is nearly always reflected in the technical quality of their roentgenograms and the accuracy of their interpretations. In this letter was also advanced the idea of organizing an exhibit of pictorial photography in connection with The Congress of Radiology, which is to be held at the Palmer House, Chicago, September 25 to September 30.

The publication of this letter brought forth a sufficient number of replies to indicate considerable interest, and steps toward the organization of such an exhibit were taken. In this exhibit strictly medical photography will have no part; only general pictorial photography (landscape, portrait or genre) will be included. A committee consisting of Dr. C. D. Enfield, Louisville, Kentucky, Dr. E. A. Merritt, Washington, D. C., and Dr. A. U. Desjardins, Rochester, Minnesota, was organized. Also, a committee of three judges, consisting of Dr. F. W. Burcky, Evanston, Illinois, Dr. Max Thorek, Chicago, Illinois, and Mr. G. H. High, Chicago Camera Club, Chicago, Illinois, has been appointed to pass on the individual exhibits and determine the two contributors who deserve the first and second prizes. The Eastman Kodak Company has graciously offered, as a first prize, a Kodak Recomar #33, which is equipped with an f. 4.5 Anastigmat lens, Compur shutter, 3 single plate holders and film sheaths, film pack adapter, exposure table and brown cowhide carrying case to hold camera, plate holders and film pack adapter. As a second prize, they offer a Kodak Six-16, which is equipped with an f.6.3 lens, with a Diodak shutter.

The space reserved for the exhibit is naturally limited, and already nine members of the various societies taking part in the Congress have undertaken to contribute to this exhibit.

Under different circumstances, it would have been advisable to conduct this exhibit strictly according to salon rules, but inasmuch as the object of this first exhibit is to stimulate interest in the photographic side of roentgenology by leading as many roentgenologists as possible to take up photography as a hobby, it was been thought best to allow some latitude. Therefore, the contributors will be allowed to mount, mat or frame their prints according to their own taste.

If this first exhibit should prove as successful as it now promises to be, and if it should stimulate sufficient interest, future exhibits should be conducted according to salon rules.

A. U. Desjardins
Chairman

In connection with the above announcement of an exhibit of pictorial photography at the American Congress of Radiology, the following item taken from the *New York Times*, July 27, 1933, would seem of interest:

THE FIRST PHOTOGRAPHER

The little town of Châlon-sur-Saône has settled down to normal life after having paraded around the statue of Joseph Nicephore Niepce in its public square and crowded into the unpretentious museum where a few relics of his inventive activity are preserved. For Niepce, who shares with Daguerre the honor of having discovered photography, died a hundred years ago in near-by Gras. Probably the

hundred million amateur photographers who press bulbs all over the world are unaware of their debt to him. Out of his simple process of making pictures on metal plates coated with asphaltum came both photo-engraving and the enormous industry of manufacturing lenses, roll films and paper for men and women to whom a camera has become an ordinary utensil.

Who has not seen linen bleached by the sun and posters fading on fences? Observation thus simple started WEDGWOOD on his experiments and inspired NIEPCE. The wonder is that out of it DAGUERRE, NIEPCE's parnter, could devise the process of developing and fixing an image formed by a lens. These men were not chemists but empiricists, who floundered not in darkness but in dazzling sunlight. It is admirable to follow a program based on a definite theory, as does a modern research scientist, but there is something more romantic about these two, depending more on brilliant intuitions than on strict reasoning in quest of a process which would take the place of the artist and the engraver. If ever a discovery was made as the result of sheer imagination and unflagging industry it was that of photography.

Yet it is to formal research that the final victory has come—if final can ever be used in speaking of any scientific inquiry. Ultra-violet regions, infra-red rays of the spectrum—of these NIEPCE and DAGUERRE knew little if anything. To photograph by light to which we are blind, to look at the world with a lens that sees only infra-red—we are still astonished at the feat. These are the natural consequences of that research in organic chemistry which has given us extraordinary ray filters and dyes. Out of NIEPCE's work in preparing pictures which could be printed like a lithograph, out of DAGUERRE's process of developing and fixing an image came photochemistry and then photosynthesis. Between the emulsion that transcribes a smile and the plant that with the aid of sunlight builds up green foliage, there is a kinship still to be discovered. For the rays with which NIEPCE and DAGUERRE only toyed, as it seems to us now, are the rays of life itself.

ERRORS IN DIAGNOSIS OF FREE PLEURAL EFFUSIONS

To the Editor:

I have just read with considerable interest the case report entitled "An Unusual Case of Pleural Effusion Simulating Elevation of the Diaphragm" by Drs. Yater and Rodis which appeared in the June, 1933, number of the Journal. In this connection I am constrained to call attention to two papers which I published in 1931. The first entitled "Roentgen Diagnosis of Small Pleural Effusions" appearing in the *Journal of the American Medical Association*, Vol. 96, page 104, contains illustrations (Fig. 1) of a case exactly similar in its roentgen manifestations to that reported by Yater and Rodis. In the caption the resemblance of the fluid to a high diaphragm is noted and the change in appearance with the patient supine is also shown. The second article entitled "Roentgenologic Observations on the Movement of Pleural Effusions" appeared in Vol. 25, page 220, of this Journal. In Figure 5 a somewhat similar case is illustrated. I have observed several others of this type in addition.

I call attention to these two papers particularly because in both of these the fact that free pleural effusions may move freely in the pleural cavity and may take on most unorthodox positions is emphasized. From my observation the phenomenon reported by Yater and Rodis is not surprising. The explanation, I believe, lies in a change in the elasticity of the lung underlying the fluid. The ordinary textbook conception of a pleural effusion distributing itself in an S-shaped curve along the periphery of the chest occurs principally in those cases wherein the normal elasticity of the lung and hence the negative pressure in the pleural cavity has been preserved. If that elasticity is interfered with for any reason or the negative intrapleural pressure changed the roentgen appearance of the fluid will take on a different form. This is true in many cases of cardiac decompensation particularly, but will also occur in other conditions.

It should be emphasized that the textbook descriptions of the roentgen appearance of pleural effusions apply only to a certain percentage of the cases. I have recently observed some cases, which will be reported in detail later, in which a free

effusion was confined entirely to the mediastinal pleural space in the erect position, closely simulating a mediastinal mass or an enlarged heart. Every case in which pleural effusion is suspected should be examined in a variety of positions to avoid error.

Leo G. Rigler

Minneapolis, Minn.

PACIFIC ROENTGEN CLUB

Open Letter to Graduate and Post-Graduate Medical Schools: An association of Radiologists known as the Pacific Roentgen Club was recently formed in California. It was organized partly to further the interest of good medical care and partly to protect the position of radiology as a recognized branch of medical practice.

It has happened in the past that certain laboratory groups, under the guise of Medical Clinics and of Hospital Associations, have induced radiologists from other States to come to California, and that after arrival these men have found the positions very different from that which they anticipated.

It is therefore suggested that before roentgenologists go to the expense and trouble of coming to the Pacific Coast to take up practice, especially in connection with hospital positions, they write to one of the members of the Club and secure information concerning the status of their prospective appointments. It is believed that if such action is taken in advance the results will be more than mutually beneficial.

L. H. Garland
Secretary

450 Sutter St.,
San Francisco, Calif.

ELECTRICAL THEORY UNIFIED

Scientists can at last reconcile the classical concepts of electricity with the ultra-modern view of matter and electricity, Professor Max Born, theoretical physicist of the University of Goettingen, Germany, has just announced in a communication to the British scientific journal Nature.

Many unsuccessful attempts have been made in the last few years by eminent theorists to combine the classical concepts of electricity first expressed in a mathematical form by Clerk Maxwell in 1864 the new quantum concepts of Professors W. Pauli, Werner Heisenberg and P. A. M. Dirac. The failure of these attempts was attributable not to the quantum theory but rather to the classical concepts that did not take account of the size of the minute particle of eletricity, the electron, but considered it as a mathematical point.

Professor Born has deducted how the Maxwell equation must be changed. His treatment of the problem is based on a new method of considering the allowable states of an electrical field. The four dimensions, three of distance or space and one of time, are treated symmetrically and the principle of relativity is fulfilled.

With this new treatment Professor Born states that there is no difficulty in calculating the properties of a moving electron on the basis of the classical theory, a feat that could not be accomplished previously.

Professor P. A. M. Dirac, a leading mathematical physicist in Great Britain, gave his opinion that this reconciliation was a major advance in the understanding of matter and electricity.

Dr. Albert Einstein, Sir Arthur Eddington, Dr. Hermann Weyland and most of the leading theoretical physicists of the world have attempted to accomplish a reconciliation between the classical formulae of Maxwell and the new quantum mechanics, as part of their search for a unified field theory that would embrace in one mathematical concept the laws of electricity, magnetism, gravitation; the ultra-modern quantum laws applying to atomic entities, such as the electron and proton, and also the laws of relativity.

In 1929 Dr. Einstein announced that he had finally succeeded, after ten years of work in developing a unified field theory, only to discard it later as not quite satisfactory. Two years ago he made a preliminary report on his new efforts in that direction. He is now continuing his work on the same problem.

Professor Born's work, if not actually a complete unified field theory, at least furnishes one of its most important cornerstones. For the fitting of the electron into the old concepts of electricity constitutes one of the major problems in the search for a unified, all-embracing explanation of the constitution of matter.

Professor Born's work is purely mathematical. By substituting a few new mathematical symbols in the original formula of Maxwell he makes it possible for the electron to become a physical entity instead of being only a mere mathematical point. From being a mere abstraction, the world of the atom is raised on a par with the rest of the physical world, assuming four dimensions instead of none.

It must be remembered that the symbols in mathematical formulas are in reality keys to mysteries of matter. The symbols in Maxwell's famous formula revealed for the first time the existence of electro-magnetic waves in the physical world. Before Maxwell published it, in 1864, no one suspected their existence.

Twenty-three years later, in 1887, using the Maxwell formula as a key, Hertz discovered the electro-magnetic wave in the laboratory. About twelve years later Marconi applied these waves to wireless. And nearly another quarter-century passed before these original mathematical symbols were harnessed in the radio to carry human speech and music to the four corners of the earth.—*New York Times*, August 25, 1933.

BOOK REVIEWS

Books Received Are Acknowledged under Heading: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers as space permits.

Recent Advances in Radium. By W. Roy Ward, M.B., B.S., M.R.C.S., Medical Director and Surgeon to the Radium Institute, London, and A. J. Burden Smith, M.B., B.S., M.R.C.S., Surgeon to the Radium Institute, London. Cloth. Price, $5.00. Pp. 324, with 4 colored plates and 140 black and white illustrations. Philadelphia: P. Blakiston's Son & Co., Inc., 1933.

This small volume from the Radium Institute in London contains a well balanced, brief survey of radium therapy, as it is being carried on in the better clinics of England, Sweden, Belgium, France, and the United States. A spirit of fairness is in evidence throughout the book and the authors state that, "It is of the highest importance that the medical practitioner should realize where radium can help, where supersede and where hinder the surgeon."

A relatively small section covering 83 pages deals with general topics such as physics, action of radiation, radiosensitivity, dosage, radium apparatus, protective measures and mass radiation. Some of the best theories explaining the effect of radiation on living tissue are elaborated and a large rôle is delegated to vascular damage as the primary factor in the resolution of malignant tumors. The grading of neoplasms is clearly explained with the aid of excellent photomicrographs. Heavily filtered, platinum needles having a low radium element content and designed for implantations lasting seven or eight days are described. Although radon is recommended, gold or platinum seeds having a wall thickness of 0.5 mm. are utilized in most accessible locations. Mass radiation at a distance is designated as a most hopeful field and the types of apparatus used in the various radium clinics are carefully described.

The remainder of the book is devoted entirely to clinical problems but is subdivided into sections dealing with malignant and non-malignant conditions. In the malignant division separate chapters deal with the breast, the uterus, the tongue, the inside of the mouth, jaws and antrum; the larynx, pharynx, and esophagus; the rectum and anal canal; the skin, penis and vulva; the bladder and prostate; the eye and sarcoma. In a general way an attempt is made to discuss the anatomy, pathology, symptomatology, surgery, radium technique, prognosis and results applicable to neoplasms in each part of the body, and where several radium techniques are recognized they are all described and their good points emphasized. The Radium Institute utilizes, for the most part, a combination of weak, heavily filtered, interstitial sources and heavily filtered surface radiation delivered by multiple sources held at a distance of a few centimeters from the skin. Many drawings and photographs illustrate the good results obtained in individual cases and a fair number of statistical tables covering end-results are included. Many special pieces of apparatus, such as a seed gun, a cystoscopic implanter, etc., are illustrated.

The last twenty-nine pages deal rather sketchily with uterine hemorrhage, the various types of adenopathy and a few skin diseases. Although the material given in this section is of good quality, the subjects are so inadequately covered that the reader reaches the end of the book with the feeling that it might better have been omitted. However, the volume, as a whole, is well arranged and very readable and it can be freely recommended as one of the best reviews of the world's knowledge of radium therapy for malignant tumors now available.

Charles L. Martin

Roentgenographic Studies of the Urinary System. By William E. Lower, M.D., F.A.C.S., Chief of Department of Urology, Cleveland Clinic, Former Associate Professor of Genitourinary Surgery, Western Reserve University, Surgeon to Cleveland Clinic Hospital, and Bernard H. Nichols, M.D., F.A.C.R., Chief of Department of Roentgenology, Cleveland Clinic, Cleveland, Ohio. Cloth. Price, $16.00. Pp. 812, with 812 illustrations. St.Louis: The C. V. Mosby Company, 1933.

This work of Lower and Nichols is confined rather closely to the roentgenolgic aspects of

urology. A relatively small part of the volume is devoted to the technique of urethrography, cystography, ureterography and pyelography, including the intravenous method. There is a brief discussion of the pathology of the urinary tract, limited to such conditions as are actually demonstrable roentgenologically. The authors insist that only such findings should be included in the roentgen diagnosis, the final diagnosis being in the province of the urologist. There is also a brief chapter dealing with indications for a roentgenographic examination of the right upper abdominal quadrant for conditions which may be related to, or confused with, urinary conditions. Nearly 90 per cent of the book is devoted to roentgenograms. There are 442 cases from the authors' practice, many with several illustrations. Each roentgenogram is accompanied by a small schematic drawing to bring out essential details that might be obscured in reproduction. With each case is a brief outline, first of roentgenographic findings, then of the history with clinical and laboratory findings and the diagnosis. The cases are varied and include patients with both usual and rare pathological conditions.

This book is valuable as a reference work and a careful study should give one an excellent foundation for roentgenologic urology. We recommend it because of its large store of valuable material, the excellence of its illustrations and the conciseness and completeness with which cases are handled.

E. W. Hall

Handbuch der Rontgendiagnostik und -therapie im Kindesalter. Unter Mitwirkung von Fachgenossen. Herausgegeben von Prof. Dr. St. Engel, Leiter der Kinderklinik der Städt. Krankenanstalten, Dortmund, und Dr. L. Schall, Leiter der Kinderabteilung des Landeskrankenhauses, Homburg-Saar. Paper, price M. 72.00; bound, M. 75.00. Pp. 720, with 637 illustrations. Leipzig: Georg Thieme, 1933.

In producing a work upon so difficult a subject as diseases of childhood, St. Engel and Schall have not relied solely on their own knowledge but have inlisted the aid of specialists from numerous clinics, each separate branch of the subject being discussed by one exceptionally qualified in his specialty. The result is an excellent compilation of knowledge concerning roentgen diagnosis and therapy. The authors have carefully arranged the material so as to cover the entire field in a systematic manner.

The normal skeletal system is dealt with in a chapter on epiphyseal development and ossification centers. The diseases of the skeletal system are considered under three headings: (1) Primary disturbances in growth such as chondrodystrophies, osteopsathyroses or brittle bones, cretinism, mongolianism, etc. (2) Secondary disturbances in growth such as rachitis, scorbutus, osteitis fibrosa, Gaucher's disease, etc. (3) Inflammatory diseases such as lues, tuberculosis and osteomyelitis. These are discussed both in general and in detail and all are generously illustrated.

The diseases of the intrathoracic structures are presented in a very complete and satisfactory manner and many interesting roentgenograms are reproduced. The divisions of gastroenterology and urology are briefly considered and there are special chapters on the skull with intracranial lesions and pneumography. Nearly one-third of the volume is devoted to roentgen and radium therapy of diseases of childhood. These include tuberculosis, blood and lymph diseases, disturbances of glands of internal secretion, hypertrophies, as of tonsils and adenoids, infectious diseases and neoplasms. The special application of roentgen and radium rays to these conditions in children being even more obscure, generally speaking, than the diagnostic features of childhood diseases, this group of articles should be of considerable aid to the roentgenologist. A chapter on ultraviolet therapy and vitamin D is appended to the volume because of their general interest to radiologists and pediatricians.

For the sake of completeness the editors have included chapters on the physics of the roentgen ray. In view of the many existing volumes on physics and technique it seems unnecessary that space should be given to these subjects in a clinical work of this nature.

E. W. Hall

Vol. XXX, No. 3

DEPARTMENT OF TECHNIQUE

Department Editor: Robert B. Taft, M.D., 105 Rutledge Ave., Charleston, S. C.

A SIMPLE TECHNIQUE FOR ROENTGEN EXAMINATION OF THE PETROUS PYRAMID

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NEW YORK CITY

IN THE roentgen examination of the petrous pyramids, the view which theoretically should be of most use is that which presents these structures with least distortion and practically, it is the view which represents the pyramid as we see it when looking from the front, perpendicular to its long axis. The view is given by Stenvers' projection. Köhler[1] describes this as follows:

The patient rests prone, the head turned about 45° towards the sound side, with the nose, forehead and the zygoma of the affected side towards the plate. The central ray passes in a plane perpendicular to the horizontal through the mid-point of a line uniting the external auditory meatus with the outer margin of the orbit, which plane forms an angle of 45° with the sagittal line. It is directed from the region of the external occipital protuberance to this point and forms with the horizontal a dorso-caudal open angle of 12°.

Where relatively few such examinations were made, difficulty has often been encountered in properly positioning the patient and in accurately centering the central ray. It was also particularly difficult to obtain comparable views of both sides. The excellent apparatus that Pfeiffer[2] has devised for roentgenography of the optic foramina lends itself to modification for the roentgen examination of the petrous pyramids.

The cassette holders are placed at 45° to the horizontal instead of 37° in the Pfeiffer apparatus—the forehead rest becomes a chin rest, the forehead and nose actually resting in the angle—the chin end of the apparatus is raised so that the inclination of the apparatus is 12° to the horizontal. It is now merely necessary to change the center points of the cassettes and the apparatus is made available for the desired use. The center points are placed at the level of the center of the petrous pyramids, i.e., at the external auditory meatus, found to be approximately $5\frac{1}{2}''$ above the apex of the 90° angle in most of our patients.

We have found it necessary to center the tube by means of an adjustable pointer which fits into the tube holder in place of a cone and is at right angles to the plane of the tube. The tube is placed at the vertical working distance (we use 27″ with a General Electric XP 1 tube) and tilted at 45° to the horizontal. The pointer and the lateral distance of the tube are adjusted until the pointer touches the center mark of one cassette holder. With the apparatus remaining in position, the tube is moved an equal distance to the other side of the midline of the apparatus and the tube is tilted 45° toward the opposite cassette. The pointer should now be touching the center point of this cassette. If then the position of the apparatus is marked out on the table and the lateral distances of the tube be marked (the vertical height is kept constant) conditions can always be duplicated, the central ray will always point at the external auditory meatus on either side. A small cone is then substituted for the pointer. We believe the pointer is a neces-

Fig. 1. Photograph of apparatus showing method of centering tube. The chin end of the apparatus is elevated 12° above the forehead end.

sary adjunct since with the 12° tilt of the apparatus, lining the central ray up by eye is difficult and apt to lead to disappointment—either the cone may cut off part of the petrous pyramid or the petrous pyramid may be projected so as to overlap the occipital bone.

We have often made two exposures of each side, one lighter and one heavier exposure, since we have found the position excellent for demonstration of tip and cortical cells of the mastoid process where this is desired. This requires considerably less exposure than does the demonstration of the petrous pyramid itself.

Depending upon the type of case, we also find the following views desirable for complete roentgen examination of the mastoid processes and petrous pyramids:

(1) The usual Law position for the mastoids.

(2) A posteroanterior view of the skull, the central ray being in the same plane as that through the outer canthus of the eye and the external auditory meatus. This is made with the aid of a Potter-Bucky diaphragm. The petrous pyramids are projected, foreshortened, into the orbits.

(3) Stereoscopic anteroposterior views of the skull. The patient lies upon the table on the back, with the chin touching the chest. In the first exposure, the central ray passes from above the head through the base of the skull at an angle of 50° to the horizontal. The adjustable pointer has been found to be very useful for "lining up" in this examination also. The second exposure is made with the tube shifted the necessary stereoscopic distance farther away from the head and tilted more, as much as is necessary to have the ray again pass through the base of the skull. This examination is also

Fig. 2. The pointer has been replaced by a cone. The patient is in position, the forehead and nose touching the angle, the chin lifted as much as is necessary. The external auditory meatus is adjusted to the center line.

made with the aid of a Potter-Bucky diaphragm. The petrous pyramids are, in these views, projected above the orbits and the base of the skull, into what is practically a "top" view. The second view gives about the same result as Mayer's projection.[1]

It is not the purpose of the present discussion to present the indications for roentgen examination of the petrous pyramids nor to present cases illustrating disease of these structures. The apparatus has been described because it has simplified the technique of examination to the same degree that Pfeiffer has simplified roentgenography of the optic foramina. The illustrations, it is hoped, will sufficiently define the information to be obtained from the various views. It is possible to combine both pieces of apparatus by means of properly placed hinges. This, however, makes it somewhat too complicated for routine use in a clinic and we have found a sufficient number of uses for the 45° angle (for example, in studies of the zygoma) to justify a separate apparatus.

A further possible future modification is suggested. It would be easily possible to cut holes in the wooden framework supporting the cassettes or replace the wood by glass in such a way as to make it possible to place the part of the head to be examined exactly at the center line of the cassette or to establish new center lines for other structures which are to be examined and for which the 45° angle is necessary. These changes may, of course, be made as the need arises.

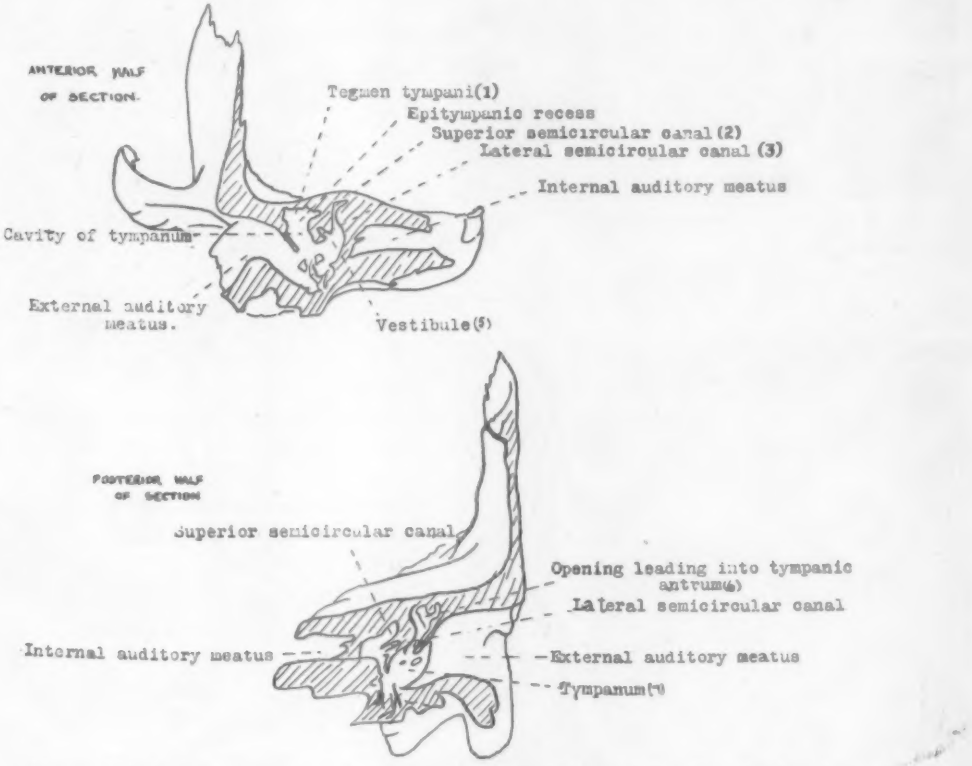

FIG. 3. Vertical transverse section through temporal bone (after Cunningham).

SUMMARY

An apparatus is described for making simple exposures of the petrous pyramids in the Stenvers projection. Several other views are described all of which should be taken for a complete examination of these

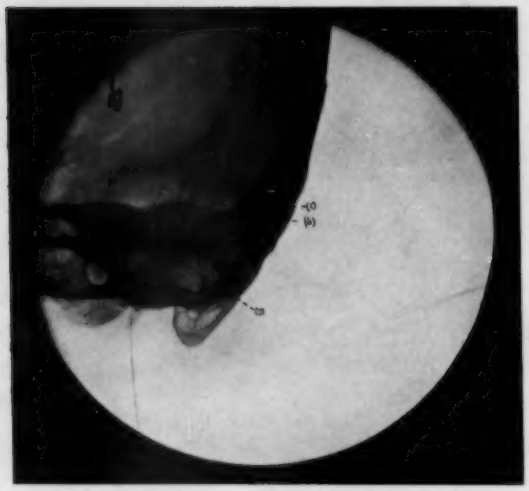

FIG. 4. Roentgenogram of anatomical specimen in the Stenvers position.

FIG. 5. Roentgenogram of the petrous pyramid in the Stenvers position. Less exposure is necessary in order to bring out the cortical and tip cells of the mastoid process.

FIG. 6. Roentgenogram showing a "top" or Mayer's position of the petrous pyramid.

structures. Information in regard to the mastoid process, antrum, tympanic ossicles, labyrinth, internal auditory meatus and middle fossa of the skull is thus made available. It should be possible to apply this complete examination in all cases of suspected inflammations, traumas and tumors involving the petrous bone.

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2. PFEIFFER, R. L. A new technique for roentgenography of the optic canals. AM. J. ROENTGENOL. & RAD. THERAPY, March, 1933, *29*, 410–415.

INDEX TO ABSTRACTS

ROENTGEN AND RADIUM THERAPY

Yater, W. M., Coe, F. O., and Rodis, Isadore: The treatment of essential hypertension by x-radiation of the medulla oblongata 420

Brunäuer, Stefan R.: Indications for roentgen therapy in skin diseases 420

Taussig, Laurence, and Morrow, Howard: Epithelioma of the skin 421

Schteingart, Mario: Exophthalmic goiter ... 421

Schreiner, Bernard F.: Tumors of the male breast, based on study of thirty-one cases .. 422

Soiland, Albert: The management of breast cancer 422

Keynes, Geoffrey: The radium treatment of carcinoma of the breast 422

Schmitz, Henry: Technic in pelvic irradiation 423

Beck, Emil G.: Some observations on the treatment of bone sarcoma 423

Lackner, Julius E., and Leventhal, M. L.: Chorionepithelioma of the uterus 423

MISCELLANEOUS

Laurell, Hugo: A method of excluding the greater part of the injurious secondary radiation in roentgenography 423

Sievert, Rolf, and Forssberg, Arne: time factor in the biological action of x-rays .. 423

Åkerlund, Åke: An improved model of serial frame 424

Lovisatti, Nicola: The action of roentgen rays on the sweat glands of man 424

Vischia, Quintino: Experiments with Busi's needle focimeter and with the metal screen focimeter 424

De Bruin, G.: The danger in using roentgen films with a base of nitrocellulose 424

Niemann, C.: The direct measurement of the tube tension in therapy with a pointer instrument 424

Heeren, J., and Hummel, R.: Variations in the lactic acid content of the blood after roentgen irradiation of normal and pathological body tissues 425

Adler, Karl, and Adler, Marg.: The effect of roentgen irradiation on the sodium content of the blood serum 425

Kading, Kurt: The effect of roentgen irradiation on the alkali reserve of the blood ... 425

Wintz, Hermann: Studies on the time factor 425

Stuhmer, A.: The need of education in roentgenology for dermatologists 426

Bircher, E.: Suit in a case of radium injury withdrawn by the plaintiff 426

Gigon, A., and Noverraz, M.: Organs as emitters of radiation 426

Neeff, Th. C.: Dosage with Sabour-aud-Noiré tablets 426

Graf, H.: On a new apparatus for superficial therapy using a combined valve roentgen tube 426

Fuhs, H., and Konrad, J.: The question of dosage in roentgen skin therapy 427

Luntz, A.: The importance of the time factor on the effect of fractional doses of radium rays upon *Eudorina elegans* 427

Suetsugu, J.: Experimental investigations on the secondary radiation of radium 427

Palmieri, G. G.: Theoretical foundations of a new method of homogeneous radiation treatment with gamma rays 428

Bode, H. G.: An additional contribution to the histology of sensitized skin radiation with roentgen rays 428

Epstein, S.: The influence of the treatment cone upon dosage 428

Fischer, A., and Horwitz, M.: Multiplication of the effect of small radium doses upon tissue cultures in vitro 428

ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN AND RADIUM THERAPY

Yater, W. M., Coe, F. O., and Rodis, Isadore. The treatment of essential hypertension by x-radiation of the medulla oblongata. *South. M. J.*, July, 1932, *25*, 730–733.

An experimental series of roentgen treatments over the medulla oblongata in patients with essential hypertension was carried out in the hope of obtaining a fall in the blood pressure. The experiment was based upon the concept that hypertension is the result of excessive stimulation of the vasomotor center, thought to be located in the fourth ventricle floor. If this center could be made less irritable, it would not respond as readily to this frequent stimulation. The authors hoped that roentgen irradiation over the site of this center might result in a raising of the threshold of excitability without injury to the numerous and delicate nerve elements in the medulla.

Eight patients received three treatments in the suboccipital region at intervals of two weeks with the following factors: 200 kv.p., 5 ma., 0.5 mm. copper and 1.0 mm. aluminum, 60 cm. for 40 minutes to an area approximately 5 cm. square, a dosage of 1,020 r within four weeks.

The patients were observed for an average of six months, without evidencing any noteworthy symptoms referable to the irradiation. Blood pressure readings were made at weekly intervals, all medication was withheld and the patients instructed to carry on their usual activities.

In 7 of the 8 cases, there was a possible effect of the irradiation upon the height of the blood pressure, manifesting itself as a tendency to lower levels. At the end of the period of observation, however, all the patients still had hypertension.

The dosage employed was greatly in excess of that used by others in the treatment of nerve ganglia for painful affections. The observations of the authors are reported to stimulate interest in this form of treatment, even though the results are not particularly encouraging. They plan to continue the experiment with larger doses from several portals of entry on patients in the fluctuating stage of hypertension, who have been carefully observed through a control period, since all patients in this series were in the fixed stage of hypertension with probable permanent organic changes in the walls of the arterioles when no treatment is of particular value.—*W. R. Brooksher, Jr.*

Brünauer, Stefan R. Indikationen zur Röntgentherapie bei Hautkrankheiten. (Indications for roentgen therapy in skin diseases.) *Strahlentherapie*, 1932, *43*, 601–630.

After discussing the theoretical bases for the use of roentgen rays in skin diseases, the author takes up some of the manifold indications for irradiation in dermatology, calling attention to the fact that no more than the absolutely necessary amount for the desired purpose should be given, as the total dose of rays that the skin can tolerate in a lifetime is limited and any later irradiation may be rendered impossible or dangerous.

There is a group of skin diseases in which roentgen irradiation is particularly indicated, including the leucemic diseases, mycosis fungoides and lymphogranulomatosis. Roentgen rays have an elective action on the leucocyte-producing organs. While irradiation has an excellent effect in these diseases it does not prevent the ultimate fatal outcome.

Irradiation is indicated in subacute and chronic eczema and neurodermatitis. Medical treatment should be tried first in acute eczema. Good results have been obtained in psoriasis by irradiation of the thymus and other endocrine glands. Lichen ruber planus has been treated successfully by a combination of roentgen rays and arsenic. Roentgen irradiation is of value in epilation for parasitic diseases of the scalp but there is some danger connected with its use on the face as the skin and salivary glands may be injured.

Roentgen irradiation is indicated only in the indurated and phlegmonous forms of acne vulgaris. In acne rosacea the results are not uniform. While in the group of keratoses a number of affections respond well to irradiation, such

as warts and plantar hyperkeratoses, others such as ichthyosis, palmar and plantar hereditary keratoma and Darier's disease are refractory.

The effects of irradiation are good in pyogenic processes, such as carbuncle and furuncle where they seem not only to have a local action but also to bring about immunity. Fried also recommends the roentgen treatment of phlegmon and erysipelas. Roentgen therapy is indicated in some forms of skin tuberculosis but because of the tendency to recurrence in lupus vulgaris, irradiation is apt to be repeated too often and injure the skin. Finsen light is therefore to be preferred. Roentgen irradiation gives excellent results in lupus follicularis disseminatus, scrofuloderma and tuberculosis verrucosa cutis. The results are uncertain in Boeck's sarcoid and erythema induratum. The results of roentgen treatment are good in actinomycosis, more particularly the cervico-facial form than the thoraco-pulmonary or intestinal form. Oral administration of potassium iodide seems to sensitize to the rays.

Roentgen irradiation is used in many forms of pruritus to control the itching. This is also its chief effect in Duhring's dermatitis herpetiformis. Pain can be controlled in the multiple forms of dermatomyoma by roentgen irradiation and the tumors also reduced in size. Roentgen therapy combined with electrocoagulation has proved valuable in the small fibromatous tumors of Recklinghausen's disease. Radium is better than roentgen irradiation for keloids, lymphomas and hemangiomas. Cavernous angiomas respond well to roentgen, radium or grenz rays. The more cavernous these tumors are the better they respond to irradiation. Plane birth marks are very little affected as they develop in intrauterine life and their radiosensitiveness is exhausted. Sarcoma multiplex hemorrhagicum reacts well to roentgen irradiation but the results are generally only symptomatic. A variety of treatments may be used in the various forms of skin cancer, including electrocoagulation, surgery and irradiation. Various forms of scleroderma are favorably affected by irradiation, either local or of the spinal column. Irradiation of the spinal column has also proved successful in sclerema neonatorum.

The fact that roentgen irradiation so frequently has to be combined with other methods in skin diseases does not lessen its value. The skill of the dermatologist is often shown in knowing how to select and combine different remedies.—*Andrey G. Morgan.*

Taussig, Laurence, and Morrow, Howard. Epithelioma of the skin. *Radiology*, Dec., 1931, *17*, 1281–1286.

The diagnostic features of these lesions are discussed. The type of therapy employed depends on the individual lesions. Treatment by means of radiotherapy should aim at giving an adequate dose at the beginning of treatment. In lesions where the least amount of destruction possible is indicated, radium alone is given preference over roentgen rays. Where there are no contraindications the authors prefer to curette the lesions and cauterize the base. This is followed, particularly in squamous cell lesions, by the application of radon tubes. Lesions previously subjected to unsuccessful irradiation are treated by means of radical surgery. Regional lymph nodes are not removed unless clinically involved. Operation should include the entire lymph chain; prophylactic irradiation of lymph chains is of questionable value. If inoperable, involved nodes are treated by means of gold emanation seeds.—*E. I. L. Cilley.*

Schteingart, Mario. Le goitre exophthalmique; (étude clinique et anatomique). (Exophthalmic goiter; clinical and anatomic study.) *Rev. sud.-am. de méd. et de chir.*, Nov., 1931, *2*, 1073–1110.

This article represents a detailed study of the clinical, biochemical, anatomic and therapeutic aspects of exophthalmic goiter on the basis of 250 cases personally observed. The procedure of treatment is summarized as follows: Two methods are used: (1) the radiotherapeutic method combined with administration of iodine and (2) the surgical method combined with iodine both in the preoperative and postoperative periods. The patient is first placed in an absolute physical and mental rest, on a high caloric diet, and on 30 drops of iodine daily. After fifteen to thirty days, radiation therapy is instituted or surgery is resorted to, depending on the general condition of the patient and the circumstances. Generally surgery is preferred to radiation. The results obtained were 70 per cent amelioration in roentgen therapy associated with iodine, 50 per cent in roentgen therapy alone, and 80 per cent after surgical intervention.—*T. Leucutia.*

SCHREINER, BERNARD F. Tumors of the male breast, based on a study of thirty-one cases. *Radiology*, Jan., 1932, *18*, 90–92.

During the years 1914 to 1931 (June), 17,486 cases were admitted to the author's tumor clinic. Included in this number were 1,664 cases of disease of the breast, 31 of which occurred in males. From this series it is concluded, (1) that carcinoma of the male breast constitutes about 1.25 per cent of all cancers of the breast; (2) carcinoma of the male breast is an uncommon disease; (3) sarcoma is rare; (4) carcinoma of the male breast is as malignant as carcinoma of the female breast and occurs, as a rule, late in life.—*Ellsworth Johnson.*

SOILAND, ALBERT. The management of breast cancer. *J. Am. M. Ass.*, March 5, 1932, *98*, 786–788.

Radiation therapy has advanced to such an extent that some surgeons are abandoning surgery in favor of radium therapy. Implantation of needles with heavy platinum filtration offers more favorable results than with the formerly used lightly filtered needles, and avoids the extensive sloughing so often obtained with the older methods.

Implantation is not easy, and bears every aspect of a major operation requiring skill and care. One hour or more is usually consumed in carefully implanting the needles in one, two, or three circles about the involved tissue, being sure that all areas of possible involvement are covered and that the needles are not within 1 cm. of bone and periosteum. Axillary and clavicular regions are included. Fifty or more needles are necessary, and 75 to 100 mg. of radium are used over a period of seven to ten days. Patients are confined to bed during treatment and usually suffer little discomfort. Precaution against radiation sickness should include alkalinization and bland diet.

The chief problem to be met is obtaining sufficient radium in the costly form of platinum needles.—*E. W. Hall.*

KEYNES, GEOFFREY. The radium treatment of carcinoma of the breast. *Brit. J. Surg.*, Jan., 1932, *19*, 415–480.

This comprehensive article covering 65 pages details the evolution during a ten-year period of the radium element needle technique now used at St. Bartholomew's Hospital in London, in the treatment of cancer of the breast. The needles are made of platinum, have wall thicknesses of 0.5 and 0.6 mm. and are of two lengths. The longer ones used in the breast and axilla have an active length of 5.0 cm. and contain 3.0 mg. of radium, whereas the shorter ones, used in the infra- and supraclavicular spaces and the intercostal spaces along the sternum, have an active length of 3.2 cm. and contain 2.0 mg. of radium. The needles are inserted into the breast so as to surround the tumor but not pass into it and so as to irradiate all of the breast tissue and its lymphatic channels. An attempt is made to place the needles parallel to one another at 1.5 cm. intervals in the breast and over the pectoralis major, and in a cone-shaped pattern in the axilla with the apex in the upper part of the space. Implantations are also made above and below the clavicle and in the intercostal spaces. The radium is usually left in place for seven days.

Many case histories and photographs of histologically proved cases are given. Small tumors frequently disappeared in five or six weeks, and marked regression was observed in more advanced conditions. Metastatic glands appeared to respond to the treatment as well as the primary tumors. In 18 cases small masses remaining in the breast after treatment were removed surgically and examined under the microscope. In 7, no evidence of cancer could be made out, while in the others small nests of malignant tissue remained in the fibrosis. In one patient pregnancy occurred two months after the treatment was carried out. Following delivery, normal lactation occurred in the treated breast and the woman has remained well for three years and ten months.

In a small number of patients, recurrences were noted in the breast or axilla but the author believes these mishaps were due to improper implantation patterns which left some of the lymphatic areas untreated. A few necroses occurred where too many needles were inserted in a small area. A study was made of one group of cases in which implantations were done following both conservative and radical removals of the breast.

A table including the main points observed in 171 cases is attached to the article. A statistical study made by Dr. Janet E. Forber, covering patients alive at the end of three years, is most interesting. There were 9 operable, 11 operable with glandular involvement, and 26

inoperable cases included; 77.7 per cent of the first group, 36.3 per cent of the second group, and 46.1 per cent of the third group were alive at the end of three years.—*C. L. Martin.*

Schmitz, Henry. Technic in pelvic irradiation. *Radiology*, Dec., 1931, *17*, 1230–1242.

The author outlines distinctly and clearly his technique for the treatment of pelvic malignancies. Intensity curves of radium applicators and bombs are illustrated. The technique of combined radium and roentgen therapy is outlined. The conditions specifically mentioned are carcinomata of the cervix, fundus, ovaries, rectum and bladder. For neoplasms in this location, the lethal dose for most mature growths with good results has been 4 to 5 E.D., for most immature groups about 2 to 2.5 E.D. This paper should be read to be appreciated.—*E. I. L. Cilley.*

Beck, Emil G. Some observations on the treatment of bone sarcoma. *Radiology*, Dec., 1931, *17*, 1270–1274.

The ideal treatment is a combination of surgery and irradiation. Two cases are described; one a sarcoma of the upper end of the femur subjected to conservative removal of the tumor and insertion of radium, apparently cured after seven years; the other a sarcoma of the wrist and the occurring of pulmonary metastasis seventeen years after operation.

The surgeon, radiologist and pathologist should cooperate in outlining the treatment of the lesion; a biopsy is important as the malignancy grading determines to a great extent the type of treatment; surgery should be of the open method to allow greater efficiency in postoperative irradiation. The case of sarcoma of the wrist was operated on and the arm amputated just below the elbow, because the tumor became so large and painful.—*E. I. L. Cilley.*

Lackner, Julius E., and Leventhal, M. L. Chorionepithelioma of the uterus; report of cure in young woman presenting extensive metastases. *J. Am. M. Ass.*, April 2, 1932, *98*, 1136–1139.

Chorionepithelioma presents great variation in clinical and pathologic characteristics and the prognosis of any given case is very much in question. The authors' case was of extremely cellular type and therefore considered very malignant. The uterus was entirely infiltrated and enlarged and extension to the vaginal wall had occurred. High voltage roentgen therapy to the pelvis was instituted and hysterectomy performed after which the patient developed a cough with blood-tinged sputum. A roentgenogram of the chest revealed extensive pulmonary metastases, and roentgen therapy was then given over this area. The metastases and local nodules in the vagina disappeared and the patient is well after five years.

The cure of the extensive disease is not easily explained. Probably the patient developed a lytic substance which destroyed the cells remaining after surgical and roentgen treatment. Radical removal and high voltage therapy are certainly the best means of combatting chorionepithelioma.—*E. W. Hall.*

MISCELLANEOUS

Laurell, Hugo. Eine Methode beim Röntgenphotographieren den grösseren Teil der schädlichen sekundärstrahung auszuschalten. (A method of excluding the greater part of the injurious secondary radiation in roentgenography.) *Acta radiol.*, 1931, *12*, 574–579.

The author describes a method of obtaining roentgenograms that are sharp and rich in contrast with hard radiation and without a Potter-Bucky diaphragm. This is accomplished by using long distances between the tube, the object and the film. The exposure time is not particularly long. An ordinary therapy tube can be used for roentgenography also and while roentgen treatment is going on several patients can be roentgenographed at the same time with the same tube.—*Audrey G. Morgan.*

Sievert, Rolf, and Forssberg, Arne. The time factor in the biological action of x-rays. *Acta radiol.*, 1931, *12*, 535–551.

The time factor when treating with protracted fractional irradiation is very complicated. In order to obtain results that can be used in radium and roentgen treatment, a large number of investigations must be made with biological objects that differ widely in nature. The authors used *Drosophila* eggs. They are not very suitable for the experiments on account of their rapid development but they are easily obtainable in large quantities, their development is particularly constant and they are very sensitive to irradiation. They were exposed to rays of varying intensity and the re-

sultant death rate determined. They were given dosages of 83 to 220 r with exposure times varying from 2.1 to 3,600 seconds. Tables and graphs are given showing the details of the results. It was found that the death rate is the same when a dose of 165 r is given over any time varying from 2.1 to 1,800 seconds. The same results are obtained with larger and smaller dosages, at least from 83 to 220 r and with irradiation times exceeding 5 to 10 seconds. The authors found, as did Packard, that with intensities below about 5 r per minute the death rate falls very rapidly; but these low intensities, which necessitate comparatively long irradiation times, are not suitable for studies of the time factor because of the rapid development of the eggs.—*Audrey G. Morgan.*

ÅKERLUND, ÅKE. An improved model of serial frame. *Acta radiol.*, 1931, *12*, 530–534.

The author describes an improved model of the duodenal serial frame that he has now been using for more than twelve years. It is entirely of metal and by its use 4 erect pictures can be taken on one 18″×24″ film. It may be provided with a cylindrical or conical anterior diaphragm. The conical diaphragm is particularly adapted for use in oblique projections and because of its conical shape causes very little inconvenience even to sensitive patients. Both the cylindrical and conical diaphragms may be provided with different compression caps either in the form of aluminum cups or pneumatic rubber compressors attached to the brim of the tube facing the patient. The serial frame can be used without either the diaphragms or the compressors but the quality of roentgenograms obtained with them is much better. —*Audrey G. Morgan.*

LOVISATTI, NICOLA. L'azione dei raggi X sulle ghiandole sudoripare dell'uomo. (The action of roentgen rays on the sweat glands of man.) *Arch. di radiol.*, 1931, *7*, 1107–1112.

The author irradiated a small field on the palm of the hand to determine whether roentgen irradiation causes any changes in the secretion of the sweat glands. Moderately soft rays were used up to doses of 1,500 R with a spark gap of 30 cm. and a filter of 3 mm. aluminum. With a special technique which he describes he took imprints of the mouths of the sweat glands before irradiation and up to a month afterward. There was no appreciable change in the secretion of the glands.—*Audrey G. Morgan.*

VISCHIA, QUINTINO. Alcune esperienze col focometro ad aghi di Busi e col focometro a reticella metallica. (Experiments with Busi's needle focimeter and with the metal screen focimeter.) *Arch. di radiol.*, 1931, *7*, 1094–1106.

The author describes the different methods used for determining the point of emergence of roentgen rays, and after a comparative study of Busi's needle focimeter and the focimeter with a metal grating, both of which are illustrated, he concludes that the needle focimeter is superior. He finds that variations in the charge of the tube and in the exposure time and the use of a re-enforcing screen do not change the size of the focus. The greatest perfection of detail is obtained with tubes with a linear focus. The gradation in the size of the needles and the eyes in the Busi focimeter make it possible to detect the slightest defects in construction and he advises the makers of tubes to add a focimeter test to the tag which shows the value of the charge of the tube.—*Audrey G. Morgan.*

DE BRUIN, G. Le danger des films radiographiques à base de nitrocellulose. (The danger in using roentgen films with a base of nitrocellulose.) *Acta radiol.*, 1932, *13*, 80–86.

From a theoretical and experimental study of the subject the author concludes that in storing films with a nitrocellulose base the storage room should be constructed in such a way that in case of fire the gas produced can expand freely so as to avoid explosion from compression. The films should be kept at as low a temperature as possible. They should be stored in such a way that the heat of decomposition cannot raise the temperature above the usual degree. The storage room must be well ventilated so that the gaseous products of decomposition will be carried away.—*Audrey G. Morgan.*

NIEMANN, C. Das direkte Messen der Roehrenspannung im Therapiebetrieb mit einem Zeigerinstrument. (The direct measurement of the tube tension in therapy with a pointer instrument.) *Strahlentherapie*, 1931, *41*, 199–200.

A pointer instrument which permits one to read the high voltage on the roentgen-ray tube directly is presented. It is constructed on the potentiometer principle whereby a certain measurable voltage is taken off a series of con-

stant high ohmic resistances which connect the two lines of the high voltage side, that is, which are parallel to the roentgen tube. If the voltage ratio is known, the tube voltage can be measured. The voltage taken from the potentiometer is rectified with a small rectifier tube and smoothed out by a condenser and therefore the peak voltage can be measured by means of an electrostatic voltmeter. The resistances, the condenser, the rectifier tube and its filament transformer are enclosed in oil and form a relatively small compact unit. The instrument can be used only for continuous direct current apparatus.—*Otto Glasser.*

Heeren, J., and Hummel, R. Schwankungen des Milchsaurespiegels des Blutes nach Röntgenbestrahlung von normalen und pathologischen Korpergeweben. (Variations in the lactic acid content of the blood after roentgen irradiation of normal and pathological body tissues.) *Strahlentherapie*, 1931, *42*, 784–791.

The authors report experiments which confirm the findings of Joos and Heeren that immediately after irradiation of malignant tumors there is an increase of lactic acid in the blood. On irradiating normal tissue of individuals who do not have cancer there is no increase of lactic acid and in the majority of cases it is even decreased immediately after irradiation. Patients with malignant tumors who showed a rise in the lactic acid content of the blood after irradiation of the tumor were irradiated afterward on a normal part of the body (the thigh) and showed a decrease of lactic acid. Irradiation of tuberculous or other pathological tissue except tumors caused a decrease of lactic acid in the blood immediately after the irradiation. In some cases the decrease of lactic acid had been compensated in two hours and in others there was a still further fall after this time.—*Audrey G. Morgan.*

Adler, Karl, and Adler, Marg. Der Einfluss der Röntgenbestrahlung auf den Natriumspiegel des Blutserums. (The effect of roentgen irradiation on the sodium content of the blood serum.) *Strahlentherapie*, 1931, *42*, 584–590.

The effect of roentgen irradiation on the sodium content of the blood serum was tested. In rabbits that had been given a surface dose of 1000 r the sodium content of the blood serum was reduced by from 6.54 to 15.24 per cent of its original value. There was no lowering of the sodium content of the blood in rabbits that were given the usual therapeutic doses of roentgen or radium irradiation. This disagrees with the results of Kroetz who found an increase in the sodium content of the blood after roentgen irradiation. Kroetz used a different method of determining the sodium, the gravimetric method of Kramer and Tisdall, while the authors used the iodometric method of H. Muller, and he irradiated a smaller surface, but even taking these facts into consideration the authors are unable to account for the contradiction.—*Audrey G. Morgan.*

Kading, Kurt. Die Einfluss der Röntgenbestrahlung auf die Alkalireserve des Blutes. (The effect of roentgen irradiation on the alkali reserve of the blood.) *Strahlentherapie*, 1931, *42*, 571–583.

The alkali reserve of the blood is, as a rule, constant but it is affected by different factors, such as disease, anesthesia, work, extreme changes of temperature and the action of irradiation. The values may fall decidedly in the acidotic direction but they do not rise to marked alkalosis. The author found very low, that is acid, values in genital tumors. He also found that after roentgen irradiation the alkali reserve changes; in some cases it rises in the alkalotic direction and in others falls. He has not examined a large enough number of cases so that definite conclusions can be drawn from them. In one of the cases that he describes the alkali reserve was found about the same on the different examinations. This is in agreement with the results of Michalowski who found that the alkali reserve did not fall after weeks on an acid diet, showing that the organism tries to keep the alkali reserve at the same level and is generally capable of doing so. But if examinations had been made more frequently it is probable that variations would have been found. The experiments are being continued as the effect of roentgen rays on alkali reserve is important.—*Audrey G. Morgan.*

Wintz, Hermann. Untersuchungen über den Zeitfaktor. (Studies on the time factor.) *Strahlentherapie*, 1931, *42*, 591–598.

A comparative study was made of the effect of irradiation of the ovary when the whole dose was given at once and when the fractional

method was used. It was found that the cells that were undergoing rapid division recovered very quickly from the effect of irradiation while resting cells showed a cumulative action. Applying these results to the treatment of carcinoma it would mean that the carcinoma cells would recover more quickly than the normal cells and that therefore fractional irradiation is not a good method but that the whole dose should be given at once.—*Audrey G. Morgan.*

STUHMER, A. Die Ausbildung in der Röntgenkunde auf dem Gebiet der Dermatologie. (The need of education in roentgenology for dermatologists.) *Strahlentherapie*, 1931, *42*, 599–604.

Serious mistakes have been made by dermatologists in using roentgen rays for the treatment of skin diseases. Such mistakes can be prevented only by having dermatologists trained in roentgenology. Even students of general medicine should now be given instruction in roentgenology and every university should have a chair of clinical roentgenology and an institute for teaching and research in roentgenology. Instruction should be given in roentgen physics, knowledge of roentgen apparatus, roentgen biology and general clinical roentgenology, as well as light biology and light therapy. More emphasis should be placed on roentgenology in clinical instruction. But when it comes to treating skin diseases the treatment should be in the hands of a dermatologist trained in roentgenology and not in the hands of a roentgenologist. In a skin disease such as eczema for instance the treatment must be adapted constantly to the changing conditions and a thorough understanding of these conditions is necessary in order to be successful with even salve treatment and still more in judging just the right time for the use of a given amount and kind of radiation. No amount of skill in roentgenology alone can be substituted for this intimate knowledge of the course of skin diseases so that roentgen treatment in these diseases should always be under the absolute control of the dermatologist.—*Audrey G. Morgan.*

BIRCHER, E. Suit in a case of radium injury withdrawn by the plaintiff. *Schweizer. med. Wchnschr.*, 1930, *60*, 621.

This is an interesting detailed report of a medico-legal radium case. It does not lend itself to abstracting but is recommended for study in the original because of its complete analysis of the expert testimony.—*E. A. Pohle.*

GIGON, A., and NOVERRAZ, M. Organs as emitters of radiation. *Schweizer. med. Wchnschr.*, 1930, *60*, 585.

The mitogenetic radiation (Gurwitsch) can only be detected by complicated methods. Stempell suggested, therefore, the use of the so-called Liesegang's rings which form on an ammonium bichromate gelatin plate if a drop of a 20 per cent silver nitrate solution is placed in its center. Positive reactions were obtained by him with onion roots. The authors repeated these experiments with a number of tissues, particularly carcinomatous tumors of the prostate, liver, colon, and ovary. They found that it was best to make up the gelatin plates in a dark room. Five minutes' exposure to daylight or ultraviolet rays produced a narrowing of the silver chromate rings. Moisture had the opposite effect. Carcinomatous tissue disturbs in some cases the ring formation very distinctly while other tissues had no effect at all.—*E. A. Pohle.*

NEEFF, TH. C. Zur Dosierung mit der Sabouraud-Noiré Tablette. (Dosage with Sabouraud-Noiré tablets.) *Strahlentherapie*, 1931, *41*, 114–123.

Neeff calls attention again to the fact that the method most commonly used for measuring roentgen-ray dosage with the Sabouraud-Noiré tablet, by placing this tablet and its holder in the center of the radiation beam, may easily lead to inaccuracies, especially in regard to the homogeneity of the irradiated area on the skin. This source of error is especially great when soft rays are used. In a large series of measurements and conclusions drawn therefrom the author indicates the change in radiation quantity and quality produced by the tablet and by the holder in practical therapy and presents a method which avoids these undesirable changes. The results also explain several misconceptions which have been published recently in the literature in regard to dosage measurements with the Sabouraud-Noiré tablet.—*Otto Glasser.*

GRAF, H. Ueber einen neuen Oberflächentherapie-apparat mit einer kombinierten Glühventil-Röntgenröhre. (On a new apparatus for superficial therapy using a com-

bined valve roentgen tube.) *Strahlentherapie*, 1931, *41*, 124–131.

A compact apparatus for superficial roentgen therapy is described. It embodies several new features which permit the building of a transformer, current regulator, tube stand, valve tube and roentgen tube into one flexible and movable unit. The tube is a combined valve and roentgen tube. It is mounted together with a cylindrical shaped condenser into the flexible arm of the tube stand. The base of the tube stand contains the main transformer and the filament transformers. An efficient stabilizer built upon the principle suggested by Pugno-Vanoni keeps current and voltage constant. A switchboard is not necessary since the voltage is always kept at 80 peak kv. and the current at 3 ma. The tube is completely surrounded by protective metal. The apparatus, which is built by the Siemens-Reiniger-Veifa Company of Berlin, requires only about one-third of the space of the older skin therapy machines of identical efficiency.—*Otto Glasser.*

Fuhs, H., and Konrad, J. Zur Dosierungsfrage in der Roentgen-Hauttherapie. (The question of dosage in roentgen skin therapy.) *Strahlentherapie*, 1931, *41*, 101–113.

In connection with a previous publication on late reactions of the skin after roentgen therapy, the authors give a detailed report on the technique and dosage for dermatological roentgen therapy as used on about 10,000 patients at the Vienna Dermatological Clinics of Arzt and Kerl. In a comprehensive table they collect about 40 types of dermatitis which react favorably to roentgen and grenz rays. Detailed dosage formulae and suggestions for a combination of radiation treatment with other dermatological therapeutic methods are given for each of the skin diseases enumerated in the table.—*Otto Glasser.*

Luntz, A. Ueber die Bedeutung des Zeitfaktors für die Wirkung der verzettelten Radiumbestrahlung auf Eudorina elegans. (The importance of the time factor on the effect of fractional doses of radium rays upon *Eudorina elegans*.) *Strahlentherapie*, 1931, *41*, 132–134.

The effect of fractional doses of mesothorium (0.2 mm. silver filter) upon *Eudorina elegans* depends to a large degree upon the time interval between the applications of the radiation. The author thinks that a first small radiation dose produces a reaction in the organisms which influences the resistance against further radium radiation and that this resistance depends upon the time interval. Further experiments are announced which may throw light upon this hypothesis.—*Otto Glasser.*

Suetsugu, J. Experimentelle Untersuchungen zur Frage der Radiumsekundärstrahlung. (Experimental investigations on the secondary radiation of radium.) *Strahlentherapie*, 1931, *40*, 401–426.

The intensity distribution of the secondary beta radiation for the radium preparations used for therapeutic purposes was examined by means of superficial cultures of *B. prodigiosus*, by *Ascaris* eggs and with the photographic method. Radium element was used in tubes of 6.6 and 13.3 mg. radium in platinum filters of 1 mm. thickness. Pertinax, aluminum, copper, silver and lead were used as secondary radiators. Control experiments were made with roentgen rays produced at 180 kv. and filtered with 0.5 mm. of copper, corresponding to a half-value layer of 0.95 mm. of copper. The distance of the secondary radiator from the cultures was 0.5 to 1 mm. and was always kept exactly the same in the experiments. It was found that the secondary radiation increases considerably with the increasing atomic weight for hard roentgen rays. For the emerging radiation of radium there is a minimum of secondary radiation for substances of medium atomic weight, while the secondary effect from lead is only slightly higher than that from pertinax. The experiments with *Ascaris* eggs did not show different effects for the emerging radiation but for incident radiation there was again an increase of the effect with increasing atomic weight of the secondary radiator. Anaerobic *Ascaris* eggs which were irradiated showed the same result whereby the effect of the secondary radiation from lead was about three times that of pertinax. In the photographic experiments a minimum effect of the secondary radiation for radiators of medium atomic weight was also observed for the emerging radiation and the continued increase with increasing atomic weight for the incidental radiation. It would seem from these experiments that in order to reduce the secondary radiation of filters employed in practice it is advisable to use second-

ary radiators of materials of an atomic weight in the neighborhood of zinc.—*Otto Glasser.*

PALMIERI, G. G. Theoretische Grundlagen eines neuen Verfahrens der Homogenbestrahlung mit Gammastrahlen. (Theoretical foundations of a new method of homogeneous radiation treatment with gamma rays.) *Strahlentherapie*, 1931, *40*, 470–492.

Using his compensation and superfilters which are designed to make the radiation intensities falling upon the skin from an extracorporeal radiation source homogeneous, the author calculates the radiation intensity on the surface and in the depth of various combinations of radiation sources. The theoretical results obtained by calculation were checked by ionization measurements with a Mallet-Danne ionomicrometer. It was found that an arrangement of the gamma-ray sources is possible which produces (1) a homogeneous distribution of the gamma-ray energy on the surface of an area of any desired size, (2) a homogeneous distribution of the gamma-ray energy throughout a considerable volume and to a considerable depth using any one single surface area and a battery of four radiation sources, (3) the same distribution as in (2) but using two diametrically opposed radiation sources. A series of diagrams illustrates the author's method of producing space homogeneity of gamma rays in air and in water and presents a conception of a standard technique for simplification and standardization of curie therapy.—*Otto Glasser.*

BODE, H. G. Ein weiterer Beitrag zur Histologie sensibilisierter roentgenbestrahlter Haut. (An additional contribution to the histology of sensitized skin radiation with roentgen rays.) *Strahlentherapie*, 1931, *40*, 515–545.

The skin of guinea pigs was sensitized during three days with tincture of iodine, croton oil and chrysarobin vaseline. Two weeks later the sensitized spots were completely normal macroscopically and only a very small change could be detected by histological examination. On the 5th, 7th, 9th, 11th and 15th days the sensitized spots were treated with a dose of 950 r of unfiltered roentgen rays. Two weeks after the irradiation, distinct changes in structure of the sensitized and irradiated skin areas were observed as compared with the skin which was only irradiated. The maximum of the degenerative changes for the skin treated with tincture of iodine and croton oil was found on the 9th and 7th day respectively after sensitization. For the skin sensitized with chrysarobin vaseline there was a decrease in the effect observed after the 5th day.—*Otto Glasser.*

EPSTEIN, S. Der Einfluss des Tubus auf die Dosis. (The influence of the treatment cone upon dosage.) *Strahlentherapie*, 1931, *40*, 493–507.

Various arrangements of treatment cones in deep therapy tube stands can cause variations in the radiation dose up to 20 per cent. Dosage measurements made with the Küstner "Eichstandgerät" show that these variations are caused by three factors: (1) secondary radiation of the filter, (2) stem radiation, (3) absorption in the wooden bottom of the cone. These factors have to be observed in the calculation and measurement of treatment dosages.—*Otto Glasser.*

FISCHER, A., and HORWITZ, M. Multiplikation der Wirkung kleinster Radiumdosen auf Gewebezellen in Vitro. (Multiplication of the effect of small radium doses upon tissue cultures in vitro.) *Strahlentherapie*, 1931, *40*, 465–469.

The authors irradiated cultures of osteoblasts with small doses of mesothorium with radium equivalent of about 0.25 mg. per hour and observed the inhibitory effect upon the growth of the fibroblasts. The experiments were made with the tissues at various temperatures (from 0° up to 50° C.) before and after the irradiation. The results show that the effect of small doses upon these tissue cultures can remain latent but by adding further small doses under various conditions it still can be shown to exist. The authors draw the conclusion that the absolute radiation effect does not depend upon the rate of proliferation of the tissue cells.—*Otto Glasser.*